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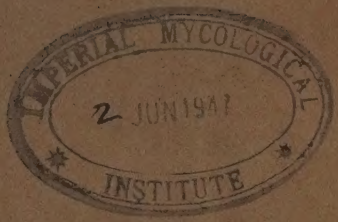

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MATHEMATICS

THE ZEROS OF L-SERIES, POWER NON-RESIDUES AND THE CLASS NUMBER OF $k(\sqrt{-D})$

By U. V. LINNIK

(Communicated by I. M. Vinogradow, Member of the Academy, 30. XII. 1942)

In the present paper I indicate certain results obtained in using the «analogy property» of L-series (1). Let $X(n)$ be a primitive non-principal character (mod D) and $N_{\min}$ the least natural number (necessarily prime) for which $X(n) \neq 1$.

There is a hypothesis, according to which $N_{\min} = O(D^{\varepsilon})$ for any $\varepsilon > 0$. Let $L(s) = \sum_{n=1}^{\infty} X(n) n^{-s} (\sigma > 0)$ be the L-series for $X(n)$. Let $\eta > 0$ be fixed and $N_{\min} > D^{\eta}$.

The «analogy property» enables us to write for $\delta > D^{-\frac{\eta}{2}}$, $\sigma_0 > 0$, $m > \frac{(\ln \ln D)^2}{\ln D}$

$$\sum_{n=1}^{\infty} \Lambda(n) X(n) n^{-s_0} e^{-(\delta n)^m} = \sum_{n=1}^{\infty} \Lambda(n) n^{-s_0} e^{-(\delta n)^m} + O(1). \qquad (1)$$

[$O(1)$ for $D \to \infty$]. Using Mellin's transformation for $\Gamma\left(\frac{s}{m}\right)$, we obtain:

$$e^{-\delta^m} = \frac{1}{2\pi i m} \int_{\alpha - i\infty}^{\alpha + i\infty} \delta^{-s} \Gamma\left(\frac{s}{m}\right) ds. \qquad (\alpha > 0). \qquad (2)$$

In using this formula as in (1) we obtain the formulae involving the poles of the function $\delta^{s-w} \Gamma\left(\frac{w-s}{m}\right) \frac{L'}{L}(w)$, on the one hand, and those of $\delta^{s-w} \Gamma\left(\frac{w-s}{m}\right) \times \times \frac{\zeta'}{\zeta}(w)$, on the other, as it was done in (1). Further application of some rather profound properties of L-series with increasing D (2) leads to two facts:

Let $0 < \alpha < 1$, $\eta > 0$ be fixed, $X(n)$ be a complex character (mod D);

$$L(s) = \sum_{n=1}^{\infty} X(n) n^{-s} (\sigma > 0); \quad r = \frac{1}{(\ln D)^{\alpha}}.$$

Iensen's theorem (3) proves that the quantity of zeros of $L(s)$ in the square $Q: 1 \geqslant \sigma \geqslant 1 - \frac{1}{(\ln D)^{\alpha}}$, $|t| \leqslant \frac{1}{2(\ln D)^{\alpha}}$, does not surpass $c_1 r \ln D$.

Theorem I. *If* $N_{\min} > D^{\varepsilon}$, *then the quantity of zeros in* Q *is* $> c_2 \times \times \frac{r \ln D}{(\ln \ln D)^{\alpha}}$.

More involved is the demonstration of

Theorem II. *Let* P *be a prime* $\equiv 1 \pmod 6$ *and* $N_{\min}$ *be the least cubic non-residue* (mod P). *Then the two inequalities* $N_{\min} > p^{\varepsilon}$; $h(-p) < c_0 \sqrt{p}\, e^{-(\ln p)^{\alpha}}$, $h(-p)$ *denoting the class number of binary quadratic forms, cannot hold simultaneously.*

These facts indicate that for the study of $N_{\min}$ the theorems analogous to the Bohr-Landau theorem (4) for L-functions with increasing D are essential. They lead to many new facts to be published in detail in the future.

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MATHEMATICS

MINIMAL AND REGULAR SYSTEMS OF FUNCTIONS

By A. T. TALDYKIN

(Communicated by S. L. Soboleff, Member of the Academy, 11. I. 1943)

We consider a system of functions from $L^2(a, b)$

$$\{\varphi_i(x)\} \tag{1}$$

with uniformly bounded norms $\varphi_{ii} = \int_a^b |\varphi_i(x)|^2 dx < M$, which is said to be regular if its main matrix

$$\Phi = \|\varphi_{ik}\|, \quad \varphi_{ik} = \int_a^b \varphi_i(x)\,\bar{\varphi}_k(x)\,dx, \quad (i, k = 1, 2, \ldots) \tag{2}$$

is regular, i. e. such as:

1) satisfies the requirement Q

$$\sum_{k=1}^{\infty} |\varphi_{ik}|^2 < +\infty, \quad (i = 1, 2, \ldots);$$

2) has a unique bounded resolvent (1).

As the Hermite matrix (2) is semi-bounded on the left, it always has a simple limiting spectral matrix

$$\|\sigma_{ik}(\mu)\|, \quad (i, k = 1, 2, \ldots). \tag{3}$$

The totality of points μ_0, for which there is no neighbourhood $\mu_0 - \varepsilon < \mu < \mu_0 + \varepsilon$ such that every $\sigma_{ik}(\mu)$ be constant, is said to be the spectrum of the matrix (2).

For every λ not belonging to the spectrum of the matrix (2) there exists a resolvent

$$\|R_{ik}(\lambda)\| = (\Phi - \lambda E)^{-1} \tag{4}$$

and this resolvent is bounded.

The elements of the resolvent may be expressed through the elements of the limit spectral matrix as follows:

$$R_{ik}(\lambda) = \int_{-\infty}^{+\infty} \frac{d\sigma_{ik}(\mu)}{\mu - \lambda} = \int_0^{+\infty} \frac{d\sigma_{ik}(\mu)}{\mu - \lambda}$$

since $\sigma_{ik}(\mu) \equiv 0$ for $\mu < 0$.

If the matrix (2) is a Q-matrix, as is the case with a regular system, then along with

$$\delta_{ik} = \int_{-\infty}^{+\infty} d\sigma_{ik}(\mu) = \int_0^{+\infty} d\sigma_{ik}(\mu)$$

there will be

$$\varphi_{ik} = \int_{-\infty}^{+\infty} \mu \, d\sigma_{ik}(\mu) = \int_{0}^{+\infty} \mu \, d\sigma_{ik}(\mu) \; (^1). \qquad (5)$$

Theorem 1. *If the matrix (2) of the system of functions (1) is a Q-matrix, it is regular. In that case the system of functions (1) is also regular by definition.*

Theorem 2. *In order that the system of functions (1) (not necessarily regular) be uniformly minimal, it is necessary and sufficient that the spectrum of its matrix (2) include no zero.*

Minimal are said to be such systems in which the removal of even only one function results in a decrease of space. Minimal systems are always B-systems, i. e. such that in $L^2(a, b)$ there is at least one system of functions

$$\{\varphi^i(x)\} \qquad (1')$$

for which the relations of biorthogonality

$$\int_a^b \varphi_i(x)\,\overline{\varphi^k}(x)\,dx = \delta_i^k \quad (i, k = 1, 2, \ldots) \qquad (B)$$

are satisfied. Conversely, B-systems are always minimal (2). If $\varphi^{ii} < M_1$, $(i = 1, 2, \ldots)$, the system (1) is said to be uniformly minimal.

There is no direct connexion between regularity and minimality of a system of functions: regular systems may be minimal or non-minimal, and minimal systems, regular or non-regular.

For every function $f(x)$ from $L^2(a, b)$ its components

$$A_\alpha = \int_a^b f(x)\,\overline{\varphi_\alpha}(x)\,dx$$

may be found from the system of functions (1), and also the coefficients of best approximation to $f(x)$ in the mean a_n^x can by means of a linear combination of order n of a system of functions be determined as numbers for which the integral

$$I(b_n^i) = \int_a^b \left| f(x) - \sum_{\alpha=1}^{n} b_n^x \varphi_\alpha(x) \right|^2 dx \quad (b_n^i = a_n^i)$$

is a minimum.

The numbers A_α and a_n^x are connected, in the case of a linearly-independent system (1), by the relations:

$$A_\alpha = \sum_{\beta=1}^{n} \varphi_{\alpha\beta} a_n^\beta,$$

$$a_n^x = \sum_{\beta=1}^{n} \varphi_n^{\alpha\beta} A_\beta, \quad (\alpha = 1, 2, \ldots, n) \; (^3).$$

In the sequel only uniformly minimal regular systems of functions (1) will be examined, and the system (1′) will be considered as adjoint to (1).

Theorem 3. *The components $\{A_\alpha\}$ of the function $f(x)$ from $L^2(a, b)$ with respect to a uniformly minimal and regular system of functions (1), and the components $\{A^\alpha\}$ of the same function with respect to system (1′) adjoined to (1) satisfy the relations*

$$\sum_{\beta=1}^{\infty} \varphi_{\alpha\beta} A^\beta = A_\alpha \quad (\alpha = 1, 2, \ldots). \qquad (6)$$

Theorem 4. *In order that the biorthogonal series*

$$\sum_{\alpha=1}^{\infty} A^{\alpha}\varphi_{\alpha}(x),\quad A^{\alpha}=\int_{a}^{b} f(x)\,\bar{\varphi}^{\alpha}(x)\,dx \tag{I}$$

for functions $f(x)$ from $L^2(a, b)$, according to a uniformly minimal and regular system (1), converge in the mean, it is necessary and sufficient that

$$\sum_{\alpha=1}^{\infty} \bar{A}_{\alpha}A^{\alpha} \tag{7}$$

be a convergent series. In that case the series (I) converges to the projection of $f(x)$ upon the space of the system (1).

If the function $f(x)$ belongs itself to the space of the system (1), the series (I) converges to this function.

Theorem 5. *The above-mentioned biorthogonal series converges in the mean if the series*

$$\sum_{\alpha=1}^{\infty} |A_{\alpha}|^2 \tag{8}$$

is a convergent series.

This follows from the fact that in this case the series (7) will converge also, since $\sum_{\alpha=1}^{\infty} \bar{A}_{\alpha}A^{\alpha} \leqslant \sum_{\alpha=1}^{\infty} |A_{\alpha}|^2 \sum_{\alpha=1}^{\infty} |A^{\alpha}|^2$; as for the series $\sum_{\alpha=1}^{\infty} |A^{\alpha}|^2$, it does always converge as a sum of squared components of the function with respect to the adjoint and, consequently, normal system ([2]).

Theorem 6. *If the series (8) is a convergent one, then*

$$\frac{1}{\lambda'}\int_{a}^{b} |\hat{f}(x)|^2 dx \leqslant \sum_{\alpha=1}^{\infty} |A_{\alpha}|^2 \leqslant \frac{1}{\lambda_1'}\int_{a}^{b} |\hat{f}(x)|^2 dx,$$

where $\hat{f}(x)=\sum_{\alpha=1}^{\infty} A^{\alpha}\varphi_{\alpha}(x)$ (in the mean) and λ_1' and λ' are the least and greatest numbers of the spectrum of the matrix (2') of the adjoined system, respectively.

Under the condition that this is a convergent series, the system (6) is solvable with respect to A^{β} ([1]):

$$A^{\beta}=\sum_{\alpha=1}^{\infty} \varphi^{\alpha\beta}A_{\alpha}\quad (\beta=1, 2, \ldots).$$

Since

$$\int_{a}^{b} |\hat{f}(x)|^2\,dx=\sum_{\alpha=1}^{\infty} \bar{A}_{\alpha}A^{\alpha}=\sum_{\alpha=1}^{\infty} \bar{A}_{\alpha}\sum_{\beta=1}^{\infty} \varphi^{\alpha\beta}A_{\beta}=\sum_{\alpha=1}^{\infty}\sum_{\beta=1}^{\infty} \varphi^{\alpha\beta}\,\bar{A}_{\alpha}A_{\beta}$$

and the matrix (2') being always bounded, we have

$$\lambda_1'\sum_{\alpha=1}^{\infty} |A_{\alpha}|^2 \leqslant \sum_{\alpha=1}^{\infty}\sum_{\beta=1}^{\infty} \varphi^{\alpha\beta}\,\bar{A}_{\alpha}A_{\beta} \leqslant \bar{\lambda}'\sum_{\alpha=1}^{\infty} |A_{\alpha}|^2,$$

from which there follows the statement made.

Theorem 7. *In order that the biorthogonal series*

$$\sum_{\alpha=1}^{\infty} A_{\alpha}\varphi^{\alpha}(x),\quad A_{\alpha}=\int_{a}^{b} f(x)\,\bar{\varphi}_{\alpha}(x)\,dx \tag{II}$$

for the function $f(x)$ from $L^2(a, b)$ with respect to the system adjoint to the uniformly minimal one be converged in the mean, it is necessary and sufficient that the series

$$\sum_{\alpha=1}^{\infty} |A_\alpha|^2 \tag{9}$$

be a convergent one.

The condition is necessary. If the series (II) converges in the mean, there exists such an $\hat{f}(x)$ in $L^2(a, b)$ that

$$\int_a^b \left| \sum_{\alpha=1}^{\infty} A^\alpha \varphi_\alpha(x) \right|^2 dx = \sum_{\alpha=1}^{\infty} \sum_{\beta=1}^{\infty} \varphi^{\alpha\beta} A_\alpha \overline{A}_\beta = \int_a^b |\hat{f}(x)|^2 dx \leqslant \int_a^b |f(x)|^2 dx.$$

Now

$$\sum_{\alpha=1}^{n} \sum_{\beta=1}^{n} \varphi^{\alpha\beta} A_\alpha \overline{A}_\beta \geqslant \lambda'^{(n)}_1 \sum_{\alpha=1}^{n} |A_\alpha|^2,$$

where $\lambda'^{(n)}_1$ is the smallest member of the spectrum of the matrix $\|\varphi^{\alpha\beta}\|_{(n)}$ $(\alpha, \beta = 1, 2, \ldots, n)$, therefore

$$\sum_{\alpha=1}^{n} |A_\alpha|^2 \leqslant \frac{1}{\lambda'^{(n)}_1} \int_a^b |\hat{f}(x)|^2 dx.$$

The minimality of the adjoint system implies that $\lim_{n\to\infty} \lambda'^{(n)}_1 = \lambda'_1 > 0$. Hence the series (9) is convergent.

The condition is sufficient. Let the series (9) converge. The series (II) will converge in the mean if and only if

$$\sum_{\alpha=m+1}^{n} \sum_{\beta=m+1}^{n} \varphi^{\alpha\beta} A_\alpha \overline{A}_\beta \to 0 \quad \text{for } m, n \to \infty.$$

We have $\sum_{\alpha=m+1}^{n} \sum_{\beta=m+1}^{n} \varphi^{\alpha\beta} A_\alpha \overline{A}_\beta \leqslant \overline{\lambda}' \sum_{\alpha=m+1}^{n} |A_\alpha|^2$, where $\overline{\lambda}'$ is the largest number of the spectrum of the matrix of the adjoint system. The adjoint system being normal, this number is a finite one, and as the series (9) converges,

$$\overline{\lambda}' \sum_{\alpha=m+1}^{n} |A_\alpha|^2 \to 0$$

for m and $n \to \infty$, which proves the sufficiency of the condition.

Corollary. The sufficient condition for the system of numbers $\{A_\alpha\}$ to be a system of components of a certain function from $L^2(a, b)$, according to the uniformly minimal system of functions (1), is that the series $\sum_{\alpha=1}^{\infty} |A_\alpha|^2$ should converge.

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ELECTRICAL ENGINEERING

AN ANALYTICAL METHOD FOR STUDYING THE WORK OF A D. C. SHUNT MOTOR WITH ROTATION SPEED CONTROLLED BY EXCITATION FLUX

By V. P. NIKITIN, Member of the Academy, V. K. TURKIN and N. P. KUNITZKI

This work is in the first place concerned with the problems involved in the calculation of transient processes in the case of a variable magnetic flux*. As for the stability of work of the motor, it is very important when dealing with a variable magnetic flux to take many more factors into consideration — in the first instance, the reaction of the armature. If these are neglected, no criterion of stability but having a limited interest can be obtained. Therefore the stability of shunt motor work in the case of a variable magnetic flux will be dealt with by the authors later, when the influence of yet another set of factors will be taken into account.

The methods generally employed in studying the transient processes in a d. c. shunt motor, when the velocity of rotation is controlled by the excitation flux, consist in integrating the differential equations of the theory of electric drive. These methods, however, do not permit in many cases to analyse the influence of the different parameters of the electric drive upon a number of quantities characterizing its work (the maximum peak of the current, the starting time and breaking period when the speed of the motor is higher than nominal, etc.). Naturally enough, the impossibility to carry out such an analysis renders much more involved the investigation of the work of a shunt motor when its rotation speed is above the nominal; it also handicaps the choice of optimal values for the parameters of the drive, and creates the necessity for making very cumbersome computations while designing the drive, as well as the braking and control rheostats. Moreover, the numerical integration of differential equations for transient processes leads usually to quite appreciable errors. On these considerations the authors propose an analytical investigation of transient processes when the speed of a shunt motor is controlled by the change of the excitation flux. This method involves the use of a certain kind of non-elementary transcendental functions.

We suppose the motor to work in the non-saturated part of its characteristic; in this case the magnetic flux Φ is proportional to the current of the excitation winding. If the influence exercised by the induction of the armature of the circuit, the reaction of the armature and the damping effect of eddy currents be neglected for the sake of simplicity, then the system of

* Together with an earlier paper by V. P. Nikitin and N. P. Kunitzki entitled «The stability of work of a d. c. shunt motor» (1), this one constitutes a part of an investigation in which the authors have been examining questions bearing on the stability of work of different types of electric drive. In the earlier paper the stability of work and the calculation of transient processes for electric drives have been discussed relative to a magnetic flux supposed to be constant.

equations of the theory of electric drive takes the following form:

$$U = Ri + c_1 i_b n, \tag{1}$$

$$c_2 i_b i = M_c + \frac{GD^2}{375} \cdot \frac{dn}{dt}, \tag{2}$$

$$U = r_b i_b + L_b \frac{di_b}{dt}, \tag{3}$$

where U is voltage at the terminals of the motor; R, resistance of the armature circuit; i, current of the armature; i_b, current of the excitation winding; n, number of rotations per minute; M_c, moment of static resistance of the mechanism; GD^2, torque of the drive; r_b, resistance of the circuit of the excitation winding; L_b, its induction; c_1 and c_2 are coefficients of proportionality varying with the constructive type of the motor.

Solving equation (3) we obtain

$$i_b = \frac{U}{r_b} + Ce^{-\frac{r_b}{L_b}t}. \tag{4}$$

Putting $e^{-\frac{r_b}{L_b}} = z$, we can rewrite the equations (1), (2) and (4) as follows:

$$i_b = \frac{U}{r_b} + Cz, \tag{5}$$

$$i = \frac{U - c_1 i_b n}{R}, \tag{6}$$

$$c_2 i_b i = M_c - \frac{GD^2 r_b}{375 L_b} z \frac{dn}{dz}. \tag{7}$$

If

$$M_c = A + Bn \tag{8}$$

(which indicates a linear characteristic of the moment of static resistance), then from (5), (6), (7) and (8) we obtain the following differential equation for n:

$$c_2 \left(\frac{U}{r_b} + Cz\right) \frac{U - c_1 \left(\frac{U}{r_b} + Cz\right) n}{R} = A + Bn - \frac{GD^2 r_b}{375 L_b} z \frac{dn}{dz}. \tag{9}$$

Equation (9) may be represented in the form

$$\frac{dn}{dz} = \frac{\alpha z^2 + \beta z + \gamma}{z} n + \frac{\delta z + \varepsilon}{z}, \tag{10}$$

where

$$\alpha = \frac{375 C^2 c_1 c_2 L_b}{GD^2 R r_b},$$

$$\beta = \frac{750 C c_1 c_2 L_b U}{GD^2 R r_b^2},$$

$$\gamma = \frac{375 L_b}{GD^2 r_b} \left(B + \frac{c_1 c_2 U^2}{R r_b^2}\right),$$

$$\delta = -\frac{375 C c_2 L_b U}{GD^2 R r_b},$$

$$\varepsilon = \frac{375 L_b}{GD^2 r_b} \left(A - \frac{c_1 U^2}{R r_b}\right).$$

Solving the differential equation (10) gives

$$n = e^{\frac{\alpha z^2}{2} + \beta z} z^{\gamma} \left[\int e^{-\left(\frac{\alpha z^2}{2} + \beta z\right)} z^{-(\gamma+1)} (\delta z + \varepsilon)\, dz + C_1 \right]. \tag{11}$$

The integral on the right-hand side of (11) cannot for arbitrary values α, β, γ, δ and ε be expressed in a finite form by elementary functions.

Introduce the notation

$$\psi(v, \lambda, \mu) = \int_1^v e^{-(h^2 + \lambda h)} h^{-\mu}\, dh \tag{12}$$

to get

$$n = e^{\frac{\alpha z^2}{2} + \beta z} z^{\gamma} \left[\delta \left(\sqrt{\frac{\alpha}{2}} \right)^{\gamma-1} \psi \left(\sqrt{\frac{\alpha}{2}} z, \beta \sqrt{\frac{2}{\alpha}}, \gamma \right) + \right.$$

$$\left. + \varepsilon \left(\sqrt{\frac{\alpha}{2}} \right)^{\gamma} \psi \left(\sqrt{\frac{\alpha}{2}} z, \beta \sqrt{\frac{2}{\alpha}}, \gamma+1 \right) + C_1 \right]$$

and, accordingly

$$n = \left(\sqrt{\frac{\alpha}{2}} \right)^{\gamma-1} \left[\delta \psi \left(\sqrt{\frac{\alpha}{2}} e^{-\frac{r_b}{L_b} t}, \beta \sqrt{\frac{2}{\alpha}}, \gamma \right) + \right.$$

$$\left. + \varepsilon \sqrt{\frac{\alpha}{2}} \psi \left(\sqrt{\frac{\alpha}{2}} e^{-\frac{r_b}{L_b} t}, \beta \sqrt{\frac{2}{\alpha}}, \gamma+1 \right) + C' \right] e^{\frac{\alpha}{2} e^{-\frac{2r_b}{L_b} t} + \beta e^{-\frac{r_b}{L_b} t} - \gamma \frac{r_b}{L_b} t} \quad (13)$$

where

$$C' = \left(\sqrt{\frac{2}{\alpha}} \right)^{\gamma-1} C_1.$$

The value of the arbitrary constant C' in formula (13) can be determined from

$$n_0 = \left(\sqrt{\frac{\alpha}{2}} \right)^{\gamma-1} e^{\frac{\alpha}{2} + \beta} \left[\delta \psi \left(\sqrt{\frac{\alpha}{2}}, \beta \sqrt{\frac{2}{\alpha}}, \gamma \right) + \right.$$

$$\left. + \varepsilon \sqrt{\frac{\alpha}{2}} \psi \left(\sqrt{\frac{\alpha}{2}}, \beta \sqrt{\frac{2}{\alpha}}, \gamma+1 \right) + C' \right],$$

where n_0 is the value of n at $t=0$.

It will be obvious that for computing n for a moment of time t we need tables of values of the functions $\psi(v, \lambda, \mu)$. Such kind of table will make it possible also to compute the value of i from formula (6). The work of setting the values of the functions $\psi(v, \lambda, \mu)$ in a tabular form is under way.

Formula (12) will be regarded as defining the functions $\psi(v, \lambda, \mu)$ for arbitrary (real or complex) values of the variables v, λ and μ. In case when v is real and positive, the integration may be made over a part of the real axis of the complex variable h from point 1 to point v. The value of arg h will be considered equal to zero at every point of the integration path. It is just the case of a real and positive v that is essential in the technical problem under consideration.

In the general case when v is arbitrary (whether real or complex) the function $\psi(v, \lambda, \mu)$ can be determined uniquely in the form of an integral in the complex plane. To our opinion, the study of this function is of mathematic interest, for by means of it a number of most remarkable functions of the calculus (Eulerian integrals, the integrals of Fresnel, Kramp's function, integral sine, cosine and logarithm) can be expressed in a very simple manner. We were able to obtain for the function $\psi(v, \lambda, \mu)$ a set of formulae, whereby its tabulating is essentially simplified.

Certain questions bearing upon the theory of shunt motor can be solved without the use of tables for the values of the function $\psi(v, \lambda, \mu)$.

Such is, for instance, the above-mentioned question as to the stability of work of this kind of motor (when the influence of the factors pointed out above, the reaction of the armature, for instance, is disregarded). The quantity n can be represented as a sum of quantities

$$n_v = \left[\frac{n_0}{\left(\sqrt{\frac{\alpha}{2}} \right)^{\gamma-1} e^{\frac{\alpha}{2} + \beta}} - \delta \psi \left(\sqrt{\frac{\alpha}{2}}, \beta \sqrt{\frac{2}{\alpha}}, \gamma \right) - \right.$$

$$\left. - \varepsilon \sqrt{\frac{\alpha}{2}} \psi \left(\sqrt{\frac{\alpha}{2}}, \beta \sqrt{\frac{2}{\alpha}}, \gamma+1 \right) \right] \times \left(\sqrt{\frac{\alpha}{2}} \right)^{\gamma-1} e^{\frac{\alpha}{2} e^{-\frac{2r_b}{L_b} t} + \beta e^{-\frac{r_b}{L_b} t} - \gamma \frac{r_b}{L_b} t}$$

(proper process) and

$$n_b = \left(\sqrt{\frac{\alpha}{2}}\right)^{\gamma-1}\left[\delta\psi\left(\sqrt{\frac{\alpha}{2}}\,e^{-\frac{r_b}{L_b}t}, \beta\sqrt{\frac{2}{\alpha}}, \gamma\right)+\right.$$

$$\left.+\varepsilon\sqrt{\frac{\alpha}{2}}\,\psi\left(\sqrt{\frac{\alpha}{2}}\,e^{-\frac{r_b}{L_b}t}, \beta\sqrt{\frac{2}{\alpha}}, \gamma+1\right)\right] e^{\frac{\alpha}{2}e^{-\frac{2r_b}{L_b}t}+\delta e^{-\frac{r_b}{L_b}t}-\gamma\frac{r_b}{L_b}t}$$

(compulsory process). In order that quantities n_c and n_b do not tend to infinity when t does, it is necessary and sufficient that the condition

$$\frac{c_1 c_2 U^2}{R r_b^2} + B > 0 \qquad (14)$$

be fulfilled $\left(\text{the quantities } \frac{GD^2}{375},\ r_b,\ L_b \text{ are regarded as positive}\right)$. When Φ and, accordingly, i_b can be considered constant, the condition for stability (14) takes the form [1]

$$\frac{kc\Phi^2}{R} + B > 0.$$

The tables giving the values of the function $\psi(v, \lambda, \mu)$ will be useful in many respects: for computing the quantities that are of interest in designing an electric drive; for analysing the influence of its parameters upon these quantities (and, consequently, for a better choice of the values of these parameters); for calculating the resistances of the steps of a shunt rheostat; for determining the time keeping of relais; for computing the strengthening or weakening of the excitation flux, etc.

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GEOPHYSICS

SOLAR RADIATION INTENSITY FOR REAL AND IDEAL ATMOSPHERE

By N. N. KALITIN

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In this country actinometric observations are organized on a large scale and carried on at stations with different climatic conditions. We dispose therefore of abundant observational data, in particular of data pertaining to the magnitude of the intensity of solar radiation, which enable us for the time being to make a number of generalizing conclusions.

At some of the stations uninterrupted observations have been carried out during more than ten years. The method of observation is identical, the setups of the same type; the material obtained is therefore absolutely uniform, which makes the comparison of the results obtained especially valuable. The results of the observations are regularly published in the Bulletin of the Permanent Actinometric Committee, according to a definite scheme. It is these data that have served as a basis for the conclusions set forth in the present note.

We made use of data of those stations where the intensity of solar radiation was measured for masses: 8, 5, 4, 3, 2, $1\frac{1}{2}$ and carried on for a sufficient number of years, viz.: Irkutsk—10 years, Wladivostok—7 years, Odessa—3 years, Eupatoria—3 years, Saratov—3 years, Ashkhabad—3 years, Yakutsk—6 years (for the latter observations for mass 11 are also available). All these stations are situated at a small altitude above the sea-level. For more southerly stations data are fewer in number, but, owing to a large number of sunny days, the bulk of the material collected even exceeds that of more northerly stations, where observations were carried out during ten years.

This article is dealing with the daily run of the magnitude of solar radiation intensity I as dependent on the mass m. Only such data were subjected to treatment, that had been derived from observations made for all masses before or after noon. Owing to this, the number of observations taken for conclusions always remained constant, whatever the mass.

The whole material to be treated was classed into groups according to the magnitudes of the common coefficient of atmosphere transparency p, every next group differing from the preceding one by 0.05; six groups thus were formed with average magnitudes of p equal to 0.60, 0.65, 0.70, 0.75, 0.80, 0.85 (for $m = 2$).

Naturally enough, the observations at extreme magnitudes of p were found to be much less numerous than those at average magnitudes. Thus, from Eupatoria there are but two series of observations with p equal to 0.60, with $p = 0.85$ they are five in number, while with $p = 0.75$ their number reaches 123 series.

For studying the magnitudes of solar radiation intensity I we took as initial magnitudes such as were obtained for an ideal atmosphere, I_{id}, by Feussner and Dubois (1), and recalculated for the European scale by Sivkov (2). All the figures given in this note are expressed in magnitudes of this scale. The classification and treatment of the observational material gave results which are tabulated below (Table 1).

Table 1

Mean Magnitudes of the Intensity of Solar Radiation for Varying m and p

p	m 8	5	4	3	2	1½	n
	h 6°.8	11°.3	14°.3	19°.3	30.°0	41.°8	
				Yakutsk			
0.65	0·29	0.42	0.55	0.67	0.84	1.02	7
0.70	0.39	0.58	0.69	0.83	0.98	1.11	8
0.75	0.52	0.73	0.83	0.96	1.13	1.26	38
0.80	0.65	0.86	0.96	1.08	1.24	1.33	45
0.85	0.74	0.95	0.07	1.19	1.32	1.44	7
				Irkutsk			
0.60	0.20	0.29	0.35	0.45	0.64	0.80	3
0.65	0.31	0.45	0.54	0.66	0.82	0.96	2
0.70	0.40	0.58	0.69	0.81	0.97	1.10	31
0.75	0.54	0.73	0.83	0.95	1.11	1.23	100
0.80	0.66	0.85	0.97	1.09	1.25	1.35	67
0.85	0.83	1.02	1.13	1.25	1.41	1.47	6
				Saratov			
0.65	0.22	0.38	0.47	0.61	0.80	0.94	6
0.70	0.36	0.55	0.67	0.80	0.96	1.09	12
0.75	0.48	0.69	0.81	0.93	1.10	1.22	52
0.80	0.62	0.82	0.92	1.05	1.21	1.32	45
				Odessa			
0.60	0.16	0.31	0.41	0.56	0,70	0.83	4
0.65	0.25	0.42	0.52	0.63	0.83	0.96	7
0.70	0.34	0.51	0.62	0.74	0.93	1.07	33
0.75	0.47	0.67	0.79	0.90	1.10	1.22	66
0.80	0.60	0.81	0.91	1.03	1.21	1.31	28
0.85	0.77	0.98	1.08	1.19	1.34	1.39	3
				Eupatoria			
0.60	0.14	0.26	0.35	0.48	0.64	0.78	2
0.65	0.27	0.44	0.52	0.65	0.84	1.01	9
0.70	0.36	0.54	0.65	0.77	0.95	1.11	58
0.75	0.47	0.68	0.78	0.92	1.09	1.20	123
0.80	0.60	0.80	0.91	1.05	1.21	1.31	54
0.85	0.71	0.92	1.01	1.13	1.30	1.36	5
				Wladivostok			
0.65	0.25	0.49	0.60	0.80	0.86	1.07	1
0.70	0.36	0.52	0.66	0.79	1.01	1.14	9
0.75	0.48	0.69	0.78	0.98	1.11	1.23	30
0.80	0.57	0.81	0.91	1.04	1.23	1.32	42
				Ashkhabad			
0.60	0.12	0.27	0.37	0.51	0.71	0.90	5
0.65	0.21	0.40	0.50	0.64	0.83	0.98	31
0.70	0.30	0.51	0.63	0.76	0.94	1.07	94
0.75	0.48	0.70	0.80	0.92	1.10	1.21	160
0.80	0.58	0.80	0.90	1.02	1.21	1.30	37
0.85	0.68	0.89	0.98	1.09	1.31	1.36	3

In this table the magnitudes of I are reduced to the mean distance between the Earth and the Sun; h is the height of the Sun corresponding to a definite mass; n is the number of observational series.

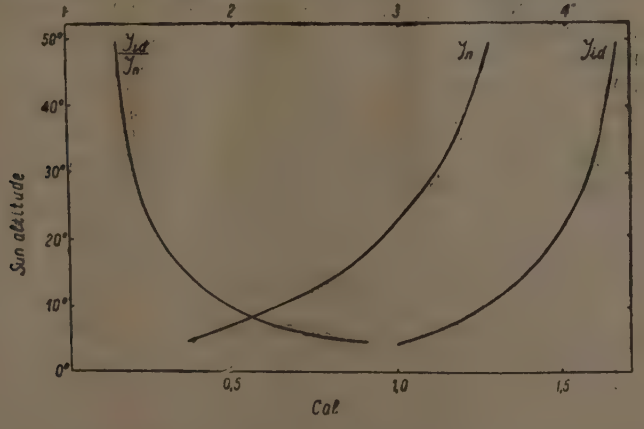
From an analysis of the material contained in Table 1 it is possible to reproduce the run of variation of the magnitude of I with the altitude of Sun and atmosphere transparency. In spite of a great diversity of climatic conditions, the magnitudes grouped according to the variations of p do but little vary from one another. This is made especially illustrative by Table 2, where the mean magnitudes of I for a p equal to 0.75 are classed according to mass.

Table 2

Mean Magnitudes of I with $p = 0.75$

Station	Mass					
	8	5	4	3	2	1½
Yakutsk	0.52	0.73	0.83	0.96	1.13	1.26
Irkutsk	0.54	0.73	0.83	0.95	1.11	1.23
Saratov	0.48	0.69	0.81	0.93	1.10	1.22
Odessa	0.47	0.67	0.79	0.90	1.10	1.22
Eupatoria	0.47	0.68	0.78	0.92	1.09	1.20
Wladivostok	0.48	0.69	0.78	0.93	1.11	1.23
Ashkhabad	0.48	0.70	0.80	0.92	1.10	1.21
Average	0.491	0.699	0.803	0.930	1.106	1.224

In this table individual magnitudes of I do so little differ from one another that one feels authorized to speak of a mean, or, in other words, a normal magnitude of the intensity of solar radiation for a mean state of



atmosphere transparency. And that a p equal to 0.75 is actually a mean magnitude, is evident from the fact that the largest number of observations, viz. 569, have been obtained with $p = 0.75$. This should be taken to mean that the condition $p = 0.75$ is the one the most frequently met with. For instance, with $p = 0.80$ there were 318 observations, with $p = 0.70$, 245 series were observed, while with the other magnitudes observations are still less numerous.

In the figure is given a normal I_n curve, referring not to atmosphere masses, but to Sun altitudes, which is of great practical interest. The curve

is somewhat extrapolated in either direction, owing to which it can be studied within a range of Sun altitudes from 5 to 50°. The same figure shows also the magnitudes of solar radiation intensity I_{id} for an ideal atmosphere.

A comparison of these curves, which is best of all characterized by the relation between the intensities of radiation at varying heights of the Sun $\left(\text{curve } \frac{I_{id}}{I_n}\text{, scale on the top of the graph}\right)$, shows that with great Sun altitudes the magnitude of I_n differs but little from that of I_{id}. This is because for an altitude of 50° the relation obtained is 1.30, while for a height of 5° it is 2.69. Besides, at great altitudes of the Sun the relation is rather constant, whereas beginning with a height of, say, 25° it begins to increase. A comparison, similar to that carried out for the magnitude of I_{id} and that of I_n, has been made for other conditions of atmosphere transparency, both better and worse. The results of this comparison are tabulated below.

Table 3

Relation between I_{id} and the Means Observed with Varying Magnitudes of Atmosphere Transparency

p \ h	5°	10°	15°	20°	25°	30°	35°	40°	45°
0.60	10.50	7.47	4.48	2.88	2.53	2.33	2.16	2.00	1.91
0.65	5.53	3.26	2.48	2.16	2.00	1.86	1.78	1.67	1.61
0.70	3.89	2.49	2.04	1.84	1.71	1.62	1.55	1.50	1.45
0.75	2.76	1.96	1.70	1.55	1.46	1.41	1.37	1.34	1.32
0.80	2.06	1.63	1.46	1.37	1.32	1.28	1.26	1.25	1.24
0.85	1.62	1.41	1.29	1.24	1.20	1.16	1.15	1.15	1.15

Table 3 shows the relation between the means for all the 7 stations, for each value of p, and the magnitude of I_{id}. In the case of a good atmosphere transparency, which occurs in the practice of actinometric observations, $\frac{I_{id}}{I}$ varies but little with height, in other words, the magnitudes of I, obtained from measurements, run almost parallel to the variation of I_{id}.

In the case of poor transparency the picture is different: at great altitudes of the Sun the variations in the radiation proceed almost parallel to changes in I_{id}. Beginning with an altitude of 20° and below, this relation is apt to vary greatly. Thus, with $p = 0.60$ for an altitude of the Sun of 5°, this relation equals 10.5, while for an altitude of 45° it is as low as 1.91.

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PHYSICAL CHEMISTRY

THE SIMILARITY OF PROCESSES OF PHYSICAL-CHEMICAL CONVERSION

By G. K. DJAKONOV

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The study of certain complex processes which defy purely mathematical analysis can successfully be realized on the basis of the principle of similarity by the method of modeling (1). It must be expected that these methods will also give fruitful results in the study of the processes of physical-chemical conversion, representing a complex of conversion phenomena in a strict sense, of phenomena of heat and mass exchange, and of momentum.

In the system of equations, describing these processes, it is the conversion equations that are fundamental. The metathetic equations and those of momentum are supplementary and may be considered as conditions necessary for a unique solution of the fundamental equations. Damköhler (2), however, when analysing the similarity of chemical processes confined himself to an analysis of the equations of heat and mass exchange, and of the equation of motion of a viscous liquid. The first two are written down for a system possessing an internal source of matter and energy. Applying the theory of similarity to the above equations, Damköhler obtains the following criteria of similarity

$$\mathrm{I}=\frac{\alpha_i u l}{c_i v},\quad \mathrm{II}=\frac{\alpha_i u l^2}{D_i c_i},\quad \mathrm{III}=\frac{Q u l}{c_p \rho \vartheta},\quad \mathrm{IV}=\frac{Q u l^2}{\lambda \vartheta}\quad \text{and}\quad \mathrm{V}=\frac{v l}{\nu}=Re.$$

From an analysis of the uniqueness conditions of the process esit may be seen that the system of equations as adopted by Damköhler is insufficient to establish the conditions of similarity. In fact, the rate of conversion is a result of the process and does not enter the conditions of its uniqueness. By eliminating this rate from the criteria I — IV, one is led to the ordinary criteria of matter and heat exchange:

$$Pe'=\frac{v l}{D_i}\quad \text{and}\quad Pe=\frac{v l}{a}.$$

Criteria I — IV are thus determinants and can be used for an analysis of the relation between the variables in the case of similarity. The problem of determining the conditions of similarity is solved by applying the following system of equations:

The equation of proportionality between the conversion of heat and the quantity of the substance converted:

$$Q_c=-q\frac{Dc_i}{dt}=\alpha_i q u_c. \qquad (1)$$

The formula of conversion (reaction) written down for the general case of a reversible process:

$$\alpha_1 A_1+\alpha_2 A_2+\ldots=\beta_1 B_1+\beta_2 B_2+\ldots \qquad (2)$$

The equation for the velocity of a reversible process (law of mass action)

$$u_c = -\frac{1}{\alpha_i} \cdot \frac{Dc_i}{dt} = \frac{1}{\alpha_i} (k_1 c_{A_1}^{\alpha_1} c_{A_2}^{\alpha_2} \ldots - k_2 c_{B_1}^{\beta_1} c_{B_2}^{\beta_2} \ldots). \tag{3}$$

Equation of matter and heat exchange

$$u_e = -\operatorname{div}(vc_i) + \operatorname{div}(D_i \operatorname{grad} c_i), \tag{4}$$

$$Q_e = -\operatorname{div}(vc_p\rho\vartheta) + \operatorname{div}(\lambda \operatorname{grad} \vartheta). \tag{5}$$

Equations of motion of a viscous liquid

$$\rho \left[\frac{\partial v}{\partial t} + (v\nabla) v \right] = \rho g - \operatorname{grad} p + \eta \left(\Delta v + \frac{1}{3} \operatorname{grad} \operatorname{div} v \right). \tag{6}$$

Equations of the relation between transformation and exchange processes

$$\frac{\partial c_i}{\partial t} + \alpha_i' u_c = u_e \tag{7}$$

and

$$\frac{\partial}{\partial t}(c_p\rho\vartheta) - Q_c = Q_e. \tag{8}$$

In the above equations: α_i denotes the stoicheiometrical conversion number; q, the thermal effect of conversion; c_i, the concentration of the component i; u_c, u_e, the velocity of conversion and exchange, respectively; Q_c and Q_e, the heat of conversion and exchange, respectively.

The other notations are those commonly used.

Equations (7) and (8) show that a complex conversion process must be represented as a dynamical equilibrium between the internal processes (variation in the contents and conversion) and the external ones (exchange). This equilibrium may be shifted in either direction, both owing to a change in the inner or in the external conditions of the process.

In establishing the conditions of similarity, equation (2) can be omitted if it is assumed that processes with the same conversion formula are studied.

The remaining equations (1, 3—8) can be reduced to two equations of the following form:

$$\frac{\partial c_i}{\partial t} + k_1 c_{A_1}^{\alpha_1} c_{A_2}^{\alpha_2} \ldots - k_2 c_{B_1}^{\beta_1} c_{B_2}^{\beta_2} \ldots = -\operatorname{div}(vc_i) + \operatorname{div}(D_i \operatorname{grad} c_i). \tag{9}$$

$$\frac{\partial}{\partial t}(c_p\rho\vartheta) - q(k_1 c_{A_1}^{\alpha_1} c_{A_2}^{\alpha_2} \ldots - k_2 c_{B_1}^{\beta_1} c_{B_2}^{\beta_2} \ldots) = -\operatorname{div}(vc_p\rho\vartheta) + \operatorname{div}(\lambda \operatorname{grad} \vartheta) \tag{10}$$

and to the equation of motion (6).

The investigation of equations (8), (9) and (10) for their invariance in the case of this conversion yields the following criteria of similarity:

criteria of homochroneity: $Ho = \frac{vt}{l}$,

conversion criteria

$$Qu = \frac{k_2 c_{B_1}^{\beta_1} c_{B_2}^{\beta_2} \ldots}{k_1 c_{A_1}^{\alpha_1} c_{A_2}^{\alpha_2} \ldots} \tag{11}$$

$$Ko = \frac{v}{k_1 c_A^{\sum \alpha - 1} l} \tag{12}*$$

exchange criteria: $Pr' = \frac{\nu}{D_i}$, $Pr = \frac{\nu}{a}$, $\frac{qc_i}{c_p\rho\vartheta}$ (13)

and criteria of motion: $Eu = \frac{\Delta p}{\rho v^2}$, $Re = \frac{vl}{\nu}$, $Ga = \frac{gl^3}{\nu^2}$.

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* When used in practice, the reciprocal quantity of the criterion Ko will probably be more convenient.

An analysis of the uniqueness conditions leads to a set of requirements, which must be satisfied independently of the invariance of the criteria of similarity as established above.

The phenomena will be similar under the following conditions:

1) the conversion formulae are identical;

2) the systems are geometrically similar;

3) the laws governing the variation of physical property as function of constitution parameters and in the course of transformation are similar;

4) the fields of the variables and of the physical constants at the initial moment are similar;

5) the conditions of matter and heat exchange at the boundaries of the system are similar.

The established conditions of uniqueness do not contain the variables u_e, u_c, p, c_{B_1}, c_{B_2}. This enables one to conclude that the criteria Qu and Eu are determinable.

As determinable criteria one can also make use of Damköhler's criteria I—IV. All the remaining criteria are determinants.

Buckingam's theorem makes it possible to represent the common integral of the system of fundamental equations in the form of either of the following two similarity equations:

$$Qu = \Phi_1\left(Ko,\ Pr',\ Pr,\ \frac{qc_i}{c_p\rho\vartheta},\ Re,\ Ga,\ K_1 \ldots\right) \tag{14}$$

or

$$\frac{\alpha_i u l}{c_i v} = \Phi_2\left(Ko,\ Pr',\ Pr,\ \frac{qc_i}{c_p\rho\vartheta},\ Re,\ Ga,\ K_1 \ldots\right) \tag{15}$$

where $K_1 \ldots$ are the neglected criteria which serve to specify the conditions of the process. Equation (14) gives the «output» of the reaction, while equation (15) — the «velocity» of the process. The relation between the functions Φ_1 and Φ_2 can be established analytically, which enables one to find experimentally only one of them.

The consideration of the physical meaning of the new criteria Qu, Ko and $\frac{qc_i}{c_p\rho\vartheta}$ obtained enables one to establish special cases of conversion processes and the corresponding special forms of the similarity equations.

The physical meaning of the criterion Qu is brought out by considering equation (3), reduced to the form:

$$\frac{\alpha_i u_c}{k_1 c_{A_1}^{a_1} c_{A_2}^{a_2}} = \frac{\alpha_i u_c}{u_i} = 1 - Qu \tag{16}$$

where

$$Qu = \frac{k_2/k_1}{\dfrac{c_{A_1}^{a_1} c_{A_2}^{a_2}}{c_{B_1}^{\beta_1} c_{B_2}^{\beta_2}}} = \frac{K_f}{K_{fc}}; \tag{17}$$

here u_i is the internal rate of the process; K_f, the constant of free equilibrium for $u_c = 0$; K_{fc}, the constant of the forced equilibrium for $u_c > 0$.

a) $u_i \to \infty$, $Qu = 1$, $K_f = K_{fc}$.

The process represents a continuous change in the state of free equilibrium, i. e. it is quasi-statical (reversible).

b) $\infty > u_i > \alpha_i u_c$, $Qu < 1$ and $K_f < K_{fc}$.

A non-statical (irreversible) process.

c) $\alpha_i u_c = u_i$, $Qu = 0$ and $K_{fc} \to \infty$.

A limiting case of non-statical (irreversible) process.

Hence the conclusion can be drawn that the criterion is that of the degree of the quasi-statical character of the process. We shall call it therefore criterion of reversibility.

The physical meaning of the criterion Ko is determined in the following way. If l is the length of the reaction zone, then $\frac{l}{v} \sim t$, where t is the time of contact; $\frac{1}{k_1 c_A^{\Sigma a - 1}} \sim \tau$, where τ is the time of decay of the component i.

Hence it follows that the criterion

$$Ko = \frac{v}{k_1 c_A^{\Sigma a - 1} l} \sim \frac{\tau}{t} \qquad (18)$$

is a measure of the ratio between the time of the decay of the initial products and the time of contact. We shall call this criterion contact criterion.

The criterion $\frac{qc_i}{c_p \rho \vartheta}$ is obtained on the basis of the requirement of the proportionality between the fluxes of heat and of matter; it brings out the relation between the fields of temperature and concentration.

Since for a quasi-statical process $Qu = 1$, the similarity equations (14) and (15) are reduced to the form:

$$Ko = \Phi_3\left(Pr', Pr, \frac{qc_i}{c_p \rho \vartheta}, Re, Ga, K_1 \ldots\right) \qquad (19)$$

and

$$\frac{a_i u l}{c_i v} = \Phi_4\left(Pr', Pr, \frac{qc_i}{c_p \rho \vartheta}, Re, Ga, K_1 \ldots\right). \qquad (20)$$

The contact criterion falls outside the class of the determining criteria and becomes determinable. This is due to the fact that for a quasi-statical process the length of the reaction zone (l) depends on the process.

For a limiting non-statical process $Qu = 0$, whence

$$\Phi_3\left(Ko, Pr', Pr, \frac{qc_i}{c_p \rho \vartheta}, Re, Ga, K_1 \ldots\right) = 0 \qquad (21)$$

which is the result of an infinite increase of the contact time $\left(Ko = \frac{\tau}{t} = 0\right)$. The process turns out to be absolutely invariant, both in the reaction-kinetical respect and with respect to the determining processes.

A comparison of the theory exposed above with the theory of heat transfer in the case of a change in the aggregate state, as formulated by Kutateladze [3], which can be considered as a particular case, leads to identical results.

Possible special comparisons with the data available for chemical conversions also lead to concordant results.

A general analysis of the conditions of similarity shows that: a) the region of quasi-statical processes admits of an exact performance of models; in the case of simple systems (e. g. with a single component) broad generalizations are possible, too; b) the region of non-statical processes must be studied with the help of methods of approximate model performance, as worked out by the school of Kirpichev [1], Member of the Academy.

The use of the methods of similarity and of model performance in the field of chemical technology is a procedure that had already been successfully applied in aerodynamics, hydrodynamics and thermokinetics. This makes one hope that it will give valuable results when applied to the field of experimental physical-chemical kinetics, as well.

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CHEMISTRY

POLYTHERM OF NaBr — KBr — H_2O TERNARY SYSTEM WITHIN A TEMPERATURE INTERVAL FROM FREEZING TO +50° C

By N. A. VLASSOV and A. G. BERGMANN

(Communicated by V. G. Chlopin, Member of the Academy, 27. XI. 1942)

Sodium bromide — potassium bromide — water is a constituent part of an aqueous reciprocal system made up by chlorides and bromides of sodium and potassium.

The investigation was carried out by the polythermal visual method.

NaBr crystallizes in different hydrate forms: $NaBr \cdot 5H_2O$ and $NaBr \cdot 2H_2O$. The intersection point of the $NaBr \cdot 5H_2O$ and $NaBr \cdot 2H_2O$ branches lies at −23.8° C and 41.8% NaBr. The $NaBr \cdot 2H_2O$ and NaBr branches intersect at +50.2° and 53.4% NaBr; the cryohydrate point is at −28.2° and 40.3% NaBr. The cryohydrate point of KBr corresponds to −12.2° and 30.6% KBr.

In an earlier paper (1) we have dwelt in detail upon the fact that on the crystallization branch of KBr two α and β polymorphous varieties of KBr have their branches intersecting each other at +22° and 40.0% KBr. The results obtained in studying the present system go to corroborate our former conclusions.

Nine cross-sections have been investigated.

In Table 1 the temperature and composition at the intersection points of the curves on the cross-sections of the system are given.

The compositions for the isothermal points −20°, −10°, 0°, +10°, +20°, +25° and 30° C, as obtained from these cross-sections, are given in Table 2. For 50° C we refer to the data obtained by F. I. Vasenin in this laboratory.

Table 1

Temperature and Composition at Intersection Points of Curves in the Cross-Sections of the System

T°	Wt % NaBr	Wt % KBr	Solid phase	T°	Wt % NaBr	Wt % KBr	Solid phase
−23.8	41.2	—	$NaBr \cdot 5H_2O$ + $+ NaBr \cdot 2H_2O$	−22.6	27.0	10.3	KBr + ice
−28.2	40.3	—	$NaBr \cdot 5H_2O$ + ice	−17.0	16.5	17.1	»
−29.6	37.4	2.0	»	−14.4	7.5	24.5	»
−24.0	39.2	2.1	$NaBr \cdot 5H_2O$ + $+ NaBr \cdot 2H_2O$	−12.2	—	30.6	»
+23.8	43.8	6.5	$NaBr \cdot 2H_2O$ + KBr	+50.0	48.15	8.18	NaBr + KBr
+ 9.0	42.4	5.4	»				
— 9.0	40.0	4.3	$NaBr \cdot 2H_2O$ + KBr				Triple points
−30.8	36.2	4.6	KBr + ice				

Table 2

Composition for Isothermal Points of NaBr—KBr—H_2O System

Wt %		Solid phase	Wt %		Solid phase
NaBr	KBr		NaBr	KBr	
		—20° Isotherm			
32.8	—	Ice	35.5	6.1	KBr
31.0	1.8	»	38.0	4.4	»
28.2	6.5	»	38.0	3.5	KBr + NaBr · $2H_2O$
22.4	13.3	KBr + ice	40.2	2.1	NaBr · $2H_2O$
26.9	10.7	KBr	41.7	—	»
		—10° Isotherm			
21.6	—	Ice	26.4	12.2	KBr
12.4	3.0	»	35.0	7.6	»
8.3	16.0	»	39.6	4.6	»
—	26.6	»	39.8	4.5	KBr + NaBr · $2H_2O$
—	31.4	KBr	40.3	4.0	NaBr · $2H_2O$
7.4	25.6	»	41.5	2.2	»
16.1	18.6	»	43.2	—	»
		0° Isotherm			
44.3	—	NaBr · $2H_2O$	34.3	9.1	KBr
43.0	2.3	»	25.9	14.0	»
41.5	4.7	»	15.8	21.0	»
41.2	4.8	NaBr · $2H_2O$ + KBr	7.1	28.2	»
39.4	6.1	KBr	—	34.0	»
		+10° Isotherm			
45.9	—	NaBr · $2H_2O$	33.8	10.6	KBr
44.4	2.4	»	25.4	15.6	»
43.0	5.0	»	15.3	23.2	»
42.6	5.4	NaBr · $2H_2O$ + KBr	6.8	30.7	»
42.3	5.7	KBr	—	36.7	»
38.6	7.9	»			
		+20° Isotherm			
47.6	—	NaBr · $2H_2O$	33.4	11.7	KBr
46.4	2.5	»	24.9	17.5	»
45.3	3.6	»	14.8	25.6	»
43.8	6.3	NaBr · $2H_2O$ + KBr	6.5	38.2	»
41.6	7.5	KBr	—	39.4	»
38.0	9.4	»			
		+25° Isotherm			
48.6	—	NaBr · $2H_2O$	33.2	12.4	KBr
47.1	2.6	»	24.6	18.4	»
45.6	5.2	»	14.6	26.8	»
44.4	6.7	NaBr · $2H_2O$ + KBr	6.4	34.4	»
41.2	8.2	KBr	—	40.6	»
37.7	10.1	»			
		+30° Isotherm			
49.4	—	NaBr · $2H_2O$	37.5	10.7	KBr
47.9	2.6	»	33.0	13.0	»
46.3	5.3	»	24.3	19.3	»
45.0	7.1	NaBr · $2H_2O$ + KBr	14.4	27.9	»
43.6	7.0	KBr	6.2	35.8	»
40.8	9.0	»	—	39.0	»
		+50° Isotherm			
49.38	6.78	NaBr	32.76	17.20	KBr
48.15	8.18	»	14.57	31.18	»
37.64	13.48	KBr	13.39	32.42	»
36.94	14.42	»	53.7	—	»
34.28	17.42	»	—	44.5	»
33.10	18.60	»			

Potassium bromide and sodium bromide from melts form solid solutions which with customary rates of cooling may be brought intact down to room temperature and decompose gradually during storage (²). From aqueous solutions KBr and NaBr crystallize out in a pure state so that no formation of solid solutions has been found by us to take place in that case. In the constitution diagram (see figure) we have fields corresponding to merely pure components of the system: ice, KBr, $NaBr \cdot 5H_2O$, $NaBr \cdot 2H_2O$ and NaBr. The field of KBr falls in turn into two, according to the two tolymorphous α and β varieties. On the diagram he boundary between those fields is marked out by a broken line.

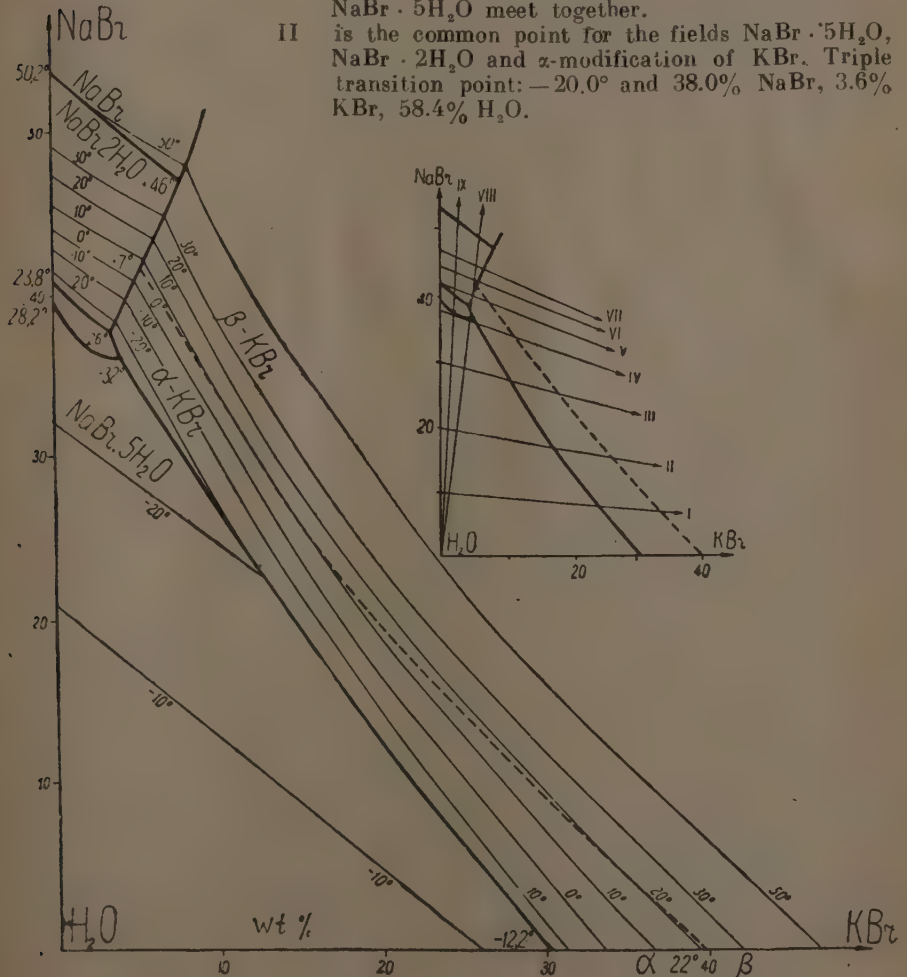
Curve of Joint Solubility for α and β KBr

T°	Wt %	
	NaBr	KBr
+22.0	—	40.0
+19.0	6.7	23.3
+16.0	14.8	25.2
+12.0	25.5	16.5
+10.0	33.8	10.6
+ 9.0	39.8	7.6

The crystallization fields meet in four triple points:

I —32.0° and 36.5% NaBr, 4.0% KBr, 59.5% H_2O is the eutectic point at which the crystallization fields of H_2O, α-KBr and $NaBr \cdot 5H_2O$ meet together.

II is the common point for the fields $NaBr \cdot 5H_2O$, $NaBr \cdot 2H_2O$ and α-modification of KBr. Triple transition point: —20.0° and 38.0% NaBr, 3.6% KBr, 58.4% H_2O.



III $+46°$ and 47.0% NaBr. 7.8% KBr, 55.2% H_2O is the meeting point of the fields $NaBr \cdot 2H_2O$, NaBr, β-KBr.

IV the fields α-KBr, β-KBr and $NaBr \cdot 2H_2O$ meet in a fourth triple point: $+7.0°$ with 41.4% NaBr, 5.4% KBr and 53.2% H_2O.

The largest in size is the field of KBr, which is in accordance with its low solubility. A very curious point to note is that, in spite of the absence of solid solutions, the temperature of the homeomorphic transformation of KBr falls, inside the system, from 22° down to $+7°$ C.A similar phenomenon has earlier been reported in the system $H_2O - KCl - KH_2PO_4$ ([1],[2]).

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CHEMISTRY

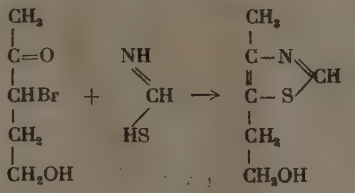
VITAMIN B_1. ON 4-METHYL-5-(β-HYDROXYETHYL)-THIAZOLE

By J. M. SLOBODIN and E. E. HELMS

(Communicated by A. E. Arbusov, Member of the Academy, 4. I. 1943)

The synthesis of the vitamin B_1 as now adopted is based on separately preparing the pyrimidine and the thiazole portion of the vitamin, and on their subsequent condensation into a molecule of aneurin.

The requisite 4-methyl-5-(β-hydroxyethyl)-thiazole is prepared for the most part according to Buchman's method [1] which consists in the condensation of bromoacetopropyl alcohol with thioformamide:



Experience has shown, however, that the vitamin prepared from such thiazole is not always sufficiently pure. And if the vitamin is determined analytically by the thiochrome method, one but rarely succeeds in obtaining a preparation with a purity of above 90%. Usually the content of the vitamin (by the thiochrome method) is much lower, occasionally as low as 30 to 40%.

Thorough examination of all the materials involved in the synthesis led us to the conclusion that 4-methyl-5-(β-hydroxyethyl)-thiazole, as prepared by Buchman's method, is by no means an individual compound. The attempts to obtain separation of the crude thiazole by repeated fractional distillations in vacuo failed to give satisfactory results. The second picrate, m. p. 91°, could not be isolated along with that previously described, m. p. 162.5°, unless there was practised precipitation of the crude thiazole in the form of picrates with subsequent fractional crystallization of the latter.

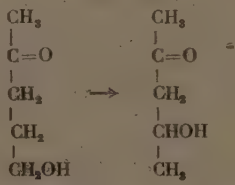
Two substances with very similar properties have been obtained by recovering thiazole from these picrates. Thiazole from the picrate with m. p. 162.5° on condensation with 2-methyl-6-amino-5-bromemethylpyrimidine yielded practically pure vitamin (98—100% by the thiochrome method). Thiazole from the picrate with m. p. 91° gave a condensation product which upon oxidation with potassium ferricyanide yielded a thiochrome-like product whose fluorescence was only 25% to that of thiochrome.

The properties of the thiazole obtained from the two picrates are shown in the table.

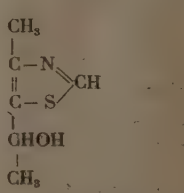
	Thiazole from picrate with m. p.	
	162.5°	91°
Boiling point	135 to 138° at 7 mm	121 to 122.5° at 2 mm
d_4^{20}	1.1984	1.1984
n_D^{20}	1.5470	1.5430
MR	37.84	37.61*
Active hydrogen (%OH)	—	10.60**

* Calculated 37.71. ** Calculated 11.88.

The thiazole from the picrate with m. p. 91° shows a positive iodoform reaction. This fact, as well as the presence of active hydrogen, points to the presence of a CH_3-CHOH group. According to our opinion, the secondary alcohol group is formed as a result of the isomerizing action of the hydrocarbonic acid, yielded in the course of the interaction of bromine with acetopropyl alcohol:



When the resulting acetoisopropyl alcohol is treated with bromine, there is formed a bromide, the condensation of which with thioformamide yields 4-methyl-5-(α-hydroxyethyl)-thiazole:



Experimental. Preparation of the Picrates. Crude thiazole, prepared by Buchman's method, was dissolved in ether. The solution was treated with a 1 to 2% ether solution of picric acid. The picrates immediately precipitated. The m.p. of the crude picrates varied from 120 to 160°, according to the composition. The picrates were crystallized from alcohol. Every fraction of the crystals was purified until crystals were obtained having a constant melting point (after 2 or 3 final crystallizations). Ultimately there was isolated the picrate described in literature with m. p. 162.5°, and the one with m. p. 91°; the latter was subjected to investigation.

Recovery of Thiazole from the Picrates. An excess of HCl was added to pure picrate. The solution was evaporated on a water bath to a small volume, diluted with water and evaporated again. Upon cooling the deposited picric acid was removed. The filtrate was alkalized with NaOH and extracted with ether. The ether solution of thiazole was dried over K_2CO_3. After removal of ether the thiazole was redistilled.

Properties of Thiazole from the Picrate with m. p. 91°. The thiazole gave a positive iodoform reaction according to Lieben. Its properties were

B. p. 121 to 122.5° at 2 mm; $d_4^{20} = 1.1984$; $n_D^{20} = 1.5430$.

Found: $MR = 37.61$.

Calcd for C_6H_9ONS: $MR = 37.71$.

Determination of active hydrogen by the Chugaev-Tzerevitinov method:

Subst. 0.1152 g; CH_4 — 17.0 ml ($t = 18°$, $p = 760$).

Found: OH — 10.56%.

Calcd for C_6H_8NSOH: OH — 11.88%.

Determination of sulphur by the Carius method:

Subst. 0.3881 g; $BaSO_4$ — 0.5735.

Found: S — 22.8%.

Calcd for C_6H_9ONS: S — 22.38%.

When this thiazole was heated to 120° with 2-methyl-6-amino-5-bromomethylpyrimidine, a condensation product was yielded in the form of a compact white mass.

The fluorescence, as found by the thiochrome analytical method, is as low as 25% of that of the pure vitamin B_1.

Conclusions. In the course of the synthesis of 4-methyl-5-(β-hydroxyethyl)-thiazole by Buchman's method there takes place a partial formation of 4-methyl-5-(α-hydroxyethyl)-thiazole, which gives a picrate with m. p. 91°.

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BIOCHEMISTRY

TETRACARBONIC DIBASIC ACIDS AS AN INTERMEDIARY LINK IN THE BIOCHEMICAL OXIDATION OF HEXOSES TO OXALIC ACID

By V. S. BUTKEVICH, Corresponding Member of the Academy, and A. A. MELNIKOVA

In our previous work on the biochemical formation of oxalic acid out of hexoses [1] we have tried to establish its maximum possible yield. Experiments with *Aspergillus niger* carried on along this line have shown that if certain conditions are available for fixing the acid formed, its yield is very near to three molecules per one molecule of the hexose consumed. However, this maximum yield has only been observed by the end of the process when the consumption of hexose was more or less complete. In the preceding phases and especially at the beginning of the process the yield of oxalic acid from the consumed sugar was always less and only gradually approached at the end of the process to its maximum value. This course of accumulation of oxalic acid points to the fact that alongside of it some other products are formed which are gradually converted to oxalic acid. A close characteristic of these products has been just the object of the investigation reported in this paper.

From the data available in literature concerning the biochemical splitting of hexoses into two and four carbon complexes, whereby such dibasic acids as the succinic and fumaric are formed [2–4], it seemed probable that in this case, too, a similar splitting occurred with the eventual oxidation of all these complexes to oxalic acid.

With this possibility in mind we tried in our further experiments on the formation from hexoses of other products, besides the oxalic acid, the ether extraction of substratum freed from oxalic acid.

This method, however, was not well fitted to the conditions under which our previous experiments had been carried out and which involved the use of alkaline phosphate for binding the acids formed. Considerable quantities of phosphoric acid passed into the ether extract, and this made difficult the investigation of the other acids present in the extract. So we gave up, in our further experiments, the use of alkaline phosphate and replaced it by sodium bicarbonate. Experiments with the latter showed, in general, the same process of oxalate accumulation as with alkaline phosphate. In all subsequent experiments the sodium bicarbonate was used both in allowing the fungous films to get rid of substances able to form oxalic acid (0.8% $NaHCO_3$) and in the test solution (1.2—2% $NaHCO_3$).

As before, the experiments were carried on at about 30° C, and in the test solution, containing 1% of glucose, the fungous films, free from substances capable of forming oxalic acid, were kept for 24 hours. Under these conditions about 0.6—0.65 g of glucose were consumed per 100 cm^3 of the experimental solution with the formation of 0.3—0.45 g of oxalic acid, the yield of the latter thus being from 1 to 1.5 molecules per molecule of the glucose consumed. From this ratio at the start of the process, while farther on the yield of oxalic acid increased to nearly 3 molecules per one molecule of consumed glucose, one naturally comes to assume the presence in the medium at that moment along with oxalic acid

of other products of glucose splitting, which are later entirely converted to oxalic acid also. Therefore t hat moment appeared to be the chosen one for the detection and investigation of the products we were interested in.

For extraction by ether we used a solution of glucose preliminarily treated with the fungous film and freed from oxalic acid by its precipitation in the form of calcium salt. The precipitation was effected by means of calcium sulphate, and the solution, after the removal of the oxalate, was on extraction by ether acidulated with sulphuric acid.

Even the first, tentative, tests showed that the acids passing into the ether extract were those carried down on its evaporation in the form of crystals. Judging by acid titration tests, melting points and some quantitative reactions, they presented a mixture of ordinary tetracarbonic dibasic acids, viz. of succinic, fumaric and malic acid. This conclusion was proved in a more definite way on a more abundant material by subdividing it into separate fractions through successive crystallization.

When the glucose solution treated with fungous films was put to the test described here, every 100 cm^3 of it was found to contain 0.308 g of oxalic acid for 0.642 g of the consumed glucose, or about 1.2 mole of the acid per one mole of the glucose consumed.

To the extraction by ether three litres of solution free from oxalic acid and cleared by charcoal were subjected. The extract obtained contained neither oxalic nor sulphuric acid. The Denigès reaction for malic acid was distinctly positive, whereas it was negative for citric acid.

The total acidity of the extracted substances and their ratio to the permanganate were characterized by the following data of titration with alkali and permanganate, as referred to the entire extract.

Total acidity corresponds to 150 cm^3 of 0.1 norm. NaOH. Reduction of 0.1 norm. $KMnO_4$ in the cold—113 cm^3; supplementary upon heating—378 cm^3.

Through fractional crystallization from water solution the substances extracted with ether were separated into four fractions.

In the first and second fractions were crystalline formations sparingly soluble in water and suggestive of fumaric acid. Denigès reaction for malic acid was negative. On the determination of melting point in closed capillaries the first fraction displayed signs of decomposition at 258—259° with breaks in the column of the substance, without clearly expressed melting. The second fraction melted at 260—262°. In the case of fumaric acid the melting temperature is 286°.

The results obtained on the titration of the separated fractions with alkali and permanganate are as follows.

	Fraction I	Fraction II
Sample (weighed on microbalance)	0.02759	0.02122
Titration with 0.1 norm. NaOH, cm^3	4.20	3.59
Corresponds to fumaric acid in g	0.0246	0.0208
Titration with 0.1 norm. $KMnO_4$, cm^3	18.6	15.6
Corresponds to fumaric acid in g(6)	0.02157	0.01758

Both preparations seemed to present fumaric acid with a certain admixture of succinic acid. In the case of fraction II calculation on the basis of titration with the permanganate permitted to evaluate the admixture of succinic acid as 15%. A similar mixture of fumaric and succinic acid composed artificially showed a melting point of about 259°, which was very close to that of the second fraction.

The crystals precipitated in the third fraction differed from those of the previous fractions by good solubility in water and in outward appearance. Their melting temperature was about 189—190°, i. e. slightly above that of succinic acid (185°) (5). A value closely corresponding to succinic acid was also obtained by titration with alkali. The sample weighed 0.02116 g. Titration absorbed 3.4 cm^3 of 0.1 norm. NaOH, which corresponds to 0.0200 g of succinic acid.

The titration of the same sample with permanganate absorbed 3.54 cm^3 of 0.1 norm. $KMnO_4$. Ascribing this value to fumaric acid, we obtain its content

in the preparation as equal to about 19%. An artificially prepared mixture with the same proportion of acids had a melting point of about 190°, i. e. very close to that obtained for the separated preparation.

In order to free the third fraction from fumaric acid, it was dissolved in water and treated with permanganate. The remainder of succinic acid in the solution was again extracted with ether. The crystals precipitated from the extract had a melting point of about 183°, i. e. one near to the melting point of succinic acid (185°) ([6]). The preparation freed from fumaric acid gave the following results on titration. Sample, 0.03306 g. Expenditure on titration, 5.56 cm³ of 0.1 norm. NaOH, which corresponds to 0.0328 g of succinic acid. Thus, the substance separated from the third fraction has been definitely identified as succinic acid. The mother liquor left behind after separation of the three crystalline fractions gave a pronouncedly positive reaction for malic acid according to Denigès. This acid was separated from the solution and identified on the basis of its melting point in the form of cinchinine salt. We found its melting point to be 188°. This figure did not agree quite satisfactorily with literary data (198°) ([7]), but was in good agreement with the melting temperature of the cinchinine salt obtained by us under similar conditions from a Kahlbaum preparation of succinic acid (187—188°).

To sum up, our experiments have furnished evidence of the formation from glucose of succinic, fumaric and malic acids, alongside of oxalic acid. However, the amount of these acids was far from corresponding to that portion of the expended glucose which was not covered by the established quantity of oxalic acid. From this it may be inferred that the list of products formed out of the consumed glucose is not exhausted by the above acids. As a product that has remained outside the sphere of this investigation, one may point perhaps to gluconic acid which is the usual product of the oxidation of glucose both in *Aspergillus niger* and in other fungi capable of the formation of oxalic acid([8]). The fact that gluconic acid may in the case of *Aspergillus niger* present a material for the formation of oxalic acid has been demonstrated by one of the present authors([9]).

Should our assumption about the intermediary formation of gluconic acid be true (to prove it further experiments are needed), then the biochemical oxidation of glucose to oxalic acid may be represented by the following scheme:

$$1)\ CH_2OH \cdot (CHOH)_4 \cdot CHO + {}^1/_2O_2 \rightarrow CH_2OH \cdot (CHOH)_4 \cdot COOH$$

$$2)\ CH_2OH \cdot (CHOH)_4 \cdot COOH + 1{}^1/_2O_2 \rightarrow (CH_2 \cdot COOH)_2 + (COOH)_2 + 2H_2O$$

$$3)\ (CH_2 \cdot COOH)_2 + 2{}^1/_2O_2 \rightarrow 2(COOH)_2 + H_2O$$

Without essentially modifying this scheme, the succinic acid may be substituted with fumaric or malic acid. Whatever may be the run of the process, it is ultimately described by the equation

$$CH_2OH \cdot (CHOH)_4 \cdot CHO + 4{}^1/_2O_2 = 3(COOH)_2 + 3H_2O.$$

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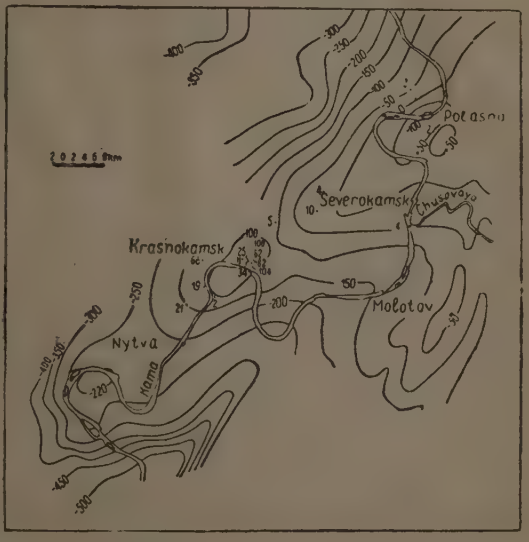
GEOCHEMISTRY

SULPHIDE WATERS OF THE PERMIAN IN THE POLASNA-KRASNOKAMSK ANTICLINE *

By A. M. KUZNETZOV

(Communicated by W. I. Vernadsky, Member of the Academy, 21. VII. 1942)

The Permian rocks of the Kama region are characterized by waters saturated with sulphur; these waters have already been used in balnaeology. A sulphide brine of an exceptionally high concentration of H_2S, reaching 1.023 g per litre (1), was obtained for the first time in 1934 at Krasnokamsk at a depth of 175.5 m from oil-bearing dolomites of the Lower Kungurian (2). Later on sulphide waters with a H_2S concentration up to 0.5 g/l and a SO_4'' concentration up to 6.0 g/l have been found in the course of boring for oil all over this region. They occupy one of the most important places among the sulphide waters of this country (3,4).



Sulphide waters are found in cavernous and fissured Kungurian and Artinskian dolomites and limestones. The water-bearing horizon is overlain by an impermeable and continuous stratum of compact anhydrites, up to 120 m thick and showing a wide regional distribution. The roof of the water-bearing horizon in the Krasnokamsk region is broken at a depth of 136 to 232 m (the structure of the roof is shown in the figure).

In Polasna the sulphate rocks outcrop at the surface; cut by the Kama river, they form an upheaval of 120 m above the river, while the dolomites of the Lower Kungurian directly underlie the fluvial alluviums (5,6). In Nytva these rocks lie as deep as 250 m.

The carbonate deposits of the Lower Kungurian and Artinskian stage contain much $CaSO_4$, $CaSO_4 \cdot 2H_2O$ and terrigenous material. Organic matter makes up on average 0.2% in carbonate rocks, and 0.5% in clays and marls. Besides, there occur pyrite and flint; NaCl (0.3%) and H_2S are also present.

* The study of the sulphide waters was made by us along with our work on the corrosion of tamponage concrete.

The dolomites of the Lower Kungurian from Polasna are strongly karstened and havenot been found to contain any hydrogen sulphide. To the south from Polasna they contain sulphide waters, springing from wells onto the surface. According to our observation, the spontaneous outflow of water decreases with time. Thus, in 1938 well 25 gave an output of 6.6 m^3 per 24 hours; by the end of 1940, the output did not surpass 3.6. Well 2 at the health-resort U.-Kachka also gave less water. These waters attend oils with a high sulphur content (3.0%).

Table 1 gives the content of waters from 6 wells, situated along the line of dip of the rocks from Polasna down to Nytva. From the data of Table 1 it may be seen that the mineralization of the waters increases with the distance of the wells from the place of the outcrop of the rocks at the surface (region of feeding); the table gives also data concerning the salt composition of the waters. It is noteworthy that the brine from well 21 which is the most remote from its source of feeding, has been found to contain calcium chlorides, while these are absent in the waters from well 4L, situated near the exposure of the rocks at the surface.

Along with the increase in the mineralization of waters, there is an accumulation of K, NH_4, Br and I. In the rocks of well 21, at a depth of 231 m, there was found 0.05% of ammonium. The Permian rocks of the Verkhny-Chusovsky region contain 0.04% of ammonium, and the waters—up to 0.45 g per litre (7).

Under laboratory conditions it was found that the solutions described are saturated up to the limit with calcium sulphate, which was to be expected judging by its content in the solid phase.

Samples from two wells, 4L and 34, have been taken for determination of gas content. Both samples, especially the second one, proved enriched with gases and biogenic nitrogen (8). The composition of the gases is shown in Table 2.

Waters of the wells 1—4 have been found to contain a high concentration of magnesium as compared to that of calcium. The accumulation of magnesium at a ratio to calcium as high as unity may be accounted for by the biogenic reduction of sulphates. A reduction of $CaSO_4$ leads to the separation of $CaCO_3$ into the solid phase, while magnesium remains in the solution by virtue of its ionic solubility (9). The quantity of $CaSO_4$ vanishing from the solution is compensated for by that newly dissolved from the rocks. Along with this, the solution takes in salts of magnesium, whereby the concentration of the latter becomes gradually increased. Many springs of the Urals have been found to show a relative accumulation of magnesium in sulphide waters. Thus, the waters of the health resort Kliuchi (10) show a content of H_2S equal to 120 mg and a total of salts equal to 2.8 g per litre, the atomic ratio being Ca : Mg = 1.

The reduction of sulphates by organic matter proceeds at high temperatures of the order of 900° and above (11). A spontaneous reduction of SO_4'' is impossible, because the transition into S″ ions is attended by an increase of the energy level. Unlike this, biogenic reduction of sulphates is of wide occurrence in nature, and has been proved experimentally (12). The presence of organic matter and of sulphates in Permian rocks is a condition necessary for this process. The discovery of anaerobic life within the earth crust at great depths (13, 14) also goes to confirm this interpretation.

The biogenic mode of formation of H_2S is also supported by the presence of fibrous onyx-like formations of calcite in Kungurian dolomites. The striated yellowish formations of $CaCO_3$ which are widely developed along the fissures of dolomites (up to 5 cm deep along the fibres of the crystals) are probably due to biogenic processes.

In the waters of well 21 the biogenic process is obscured by the metathetic reactions which lead to a change in the ratio Ca : Mg. This can be illustrated by an experiment, run in 5 replicates, on the interaction of the solutions. The experiment is started with waters from well 2, containing clay at a ratio 1 : 1, which leads to the accumulation in the solution of Ca and Mg and to a change in their ratio.

The experiment was carried out on quaternary clay having the following content: SiO_2, 59.46; Al_2O_3, 19.44; Fe_2O_3, 7.36; CaO, 2.30; MgO, 2.75; SO_3, 0.46;

Table 1

District, well, date of sampling	Depth, m	pH	Density 20°C	In grams per 1 kg of the solution												Total	$\frac{Cl}{Mg}$	$\frac{Na}{Cl}$
				Na	K	NH_4	Mg	Ca	Cl	Br	I	SO_4	$(SO_4)^*$	HCO_3	H_2S			
1. Levshino, well 4, 11.VIII. 1937 . .	40—191	6.4	1.032	13.648	not determ.	not determ.	0.721	1.219	21.569	0.026	traces	4.842	not determ.	0.256	0.350	1.427	1.03	0.97
2. Krasnokamsk, 25, 4. IX. 1939 . . .	111—360	6.8	1.027	11.957	0.125	0.031	0.679	1.131	18.434	0.039	0.003	5.214	5.265	0.500	0,410	1.274	1.01	1.00
3. Krasnokamsk, 34, 4. IX. 1939 . . .	94—360	6.9	1.039	16.757	0.108	0.026	0.675	1.218	25.979	0.026	0.002	5.180	5.200	0.512	0.370	1.698	1.09	0.99
4. Ust-Kachka, 2, 25.VII. 1940 . .	211—480	6.7	1.056	24.876	0,188	0.058	0.856	1.604	39.525	0.028	0.002	5.706	5.740	0.373	0.355	2.480	1.14	0.97
5. Ust-Kachka, 19, 16.XII 1939. . .	120—300	6.9	1.077	36.968	0.241	0.059	0.866	2.162	59.989	0.058	0.006	4.831	4.917	0.182	+ not determ.	3.592	1.51	0.95
6. Nytva, 21, 10.IX. 1940	232—240.5	6.8	1.163	64.043	0.673	0.256	3.399	10.313	126.851	0.354	0.011	0.945	0.950	0.543	+ not determ.	7.220	1.84	0.78

Note. Waters of wells 1—5 spring to the surface; sampling made at the mouth of the wells. Water 5 taken after a prolonged stop in boring, after solid phase of the washing liquid has deposited along the tube. Waters 1 and 6 are supplied from dolomites of the Lower Kungurian only, 2—5 from Kungurian-Artinskian beds. The temperature of the waters varies from 6 to 7°C.

* Concentration SO_4 after the waters have been saturated with gypsum (5 g of gypsum per 1 litre of water).

Table 2

Well, date	CO_2, H_2S	CH_4	C_2H_6 and above	N_2 and rare	A, Kr, X	He, Ne	Total	$\frac{A \cdot 100}{N_2}$	Gas elasticity in atm.
4L, 14.VIII. 1938	163.7	5.3	—	30.5	0.51	increased	199.5	1.67	2.95
34, 5. IX. 1939	216.0	13.0	0.65	38.0	0.50	»	268.7	1.32	3.15

losses by ignition, 6.72%; absorbed Ca, 394 and Mg, 111 mg-equiv. per kg. The clay was added 1% of NaCl and 2% of $CaSO_4 \cdot 2H_2O$.

Table 3

Solution	Density 20°C	In grams per 1 kg of the solution						Total	[Ca]/[Mg]	[Na]/[Cl]
		$CaCO_3$	$CaSO_4$	$MgSO_4$	$CaCl_2$	$MgCl_2$	NaCl			
Water from well 2, 27.VI. 1940	1.056	0.52	4.55	2.87	—	1.13	63.92	72.99	1.08	0.98
Water from well 2, after one interaction with clay	1.058	0.01	3.46	—	8.79	4.49	59.04	75.79	2.22	0.82
Do, after three interactions with clay . .	1.068	—	1.78	—	24.73	7.27	52.81	86.59	3.09	0.61
Do, after five interactions with clay . .	1.077	—	1.41	—	36.02	9.27	49.67	96.37	3.44	0.50

The results of this experiment, as shown in Table 3, clearly characterize the displacement of Ca and Mg of the clay by the sodium of the solution. The drop in the concentration of $CaSO_4$ is due to the appearance and growth of the concentration of $CaCl_2$ in the solution, along with the decrease in the NaCl content. This is the process that takes place in the solutions, migrating along the rocks.

The mode of distribution of the solutions in the dolomites of the Upper Kungurian at Levshino ([15]) and in the dolomites of the Lower Kungurian of the Polasna-Krasnokamsk anticline, points to an alteration in the salt composition of the solutions migrating through the rocks. This alteration proceeds according to the following scheme:

$$1)\ CaSO_4, NaCl \rightarrow 2)\ Na_2SO_4, NaCl, CaSO_4, MgSO_4 \rightarrow$$
$$\rightarrow 3)\ NaCl, MgSO_4, CaSO_4, MgCl_2 \rightarrow 4)\ NaCl, CaCl_2, MgCl_2, CaSO_4.$$

Our observations have led us to a conclusion that the formation of the salt content of the waters takes place according as the meteoritic waters, accumulating in fissured rocks, are migrating through the latter. Their migration is accompanied by an enrichment with salts and a quantitative change in the atomic composition due both to metathetic reactions and biogenic processes. The huge amount of H_2S found in these waters cannot be accounted for by anything else than the activity of reducing bacteria. Calcium sulphate and oil products present unexhaustible sources for this process.

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MICROBIOLOGY

BACTERICIDAL PROPERTIES OF FLY LARVAE

By D. N. TALIEV

(Communicated by L. A. Orbeli, Member of the Academy, 9. I. 1943)

As has been shown within recent years ([5], [6], [9]), the successful application of sterile fly larvae to surgical practice is accounted for not so much by their mechanical effect, as by the products of their secretion. Among these one of the most efficient for the purposes of therapeutics is the bactericidal principle which has been detected in the alimentary canal of fly larvae. Its effect upon the microflora responsible for wound infection has been found to be a destructive one.

The bactericidal properties referred to above have been but insufficiently investigated; the only thing known is that the bactericidal principle is contained in the intestine of *Lucilia sericata* Mg. and in the excrements of this fly. It has been proved, moreover, that it is present not all along the intestine, but only in the posterior and, partly, in the middle intestine ([7], [8]). Quite unclear, although of great interest for the purposes of practical surgery, are the following questions: first, the bactericidal effect of the larvae related to the various stages of development and, secondly, the bactericidal effect of larvae of different fly-species. Preliminary investigation in this field was carried out with several stages of larvae of *Lucilia sericata* Mg., *Musca domestica* L. and *Calliphora erythrocephala* Mg. Separate segments of the intestine were isolated after the method of sterile preparation of insect organs, as worked out by E. N. Pavlovsky, Member of the Academy ([1]).

The external covers of the larvae to be investigated were subjected to thorough sterilization. The larvae were kept during 1 hour in a 10% formalin solution with addition of 5% of antiformine. After this they were transferred for an hour into a solution of the following composition: corrosive sublimate—0.25 g; potassium chloride, 6.5 g; muriatic acid, 1.25 cm³; 96° alcohol, 250 cm³; distilled water, 750 cm³. Upon sterilization, the larvae were washed 7 times in sterile saline, narcotized with chloroform, and subjected to preparation under sterile conditions.

The preparation was carried out under a gauze tent imbibed with a 5% phenol solution, in sterile Petri dishes. During dissection the cover of the dish was held by the assistant over the dish; in the course of preparation of the intestine under a binocular glass, the field of preparation was protected from the operators breathing by a sheet of paper sterilized with dry heat.

After the larva had been transferred into a Petri dish, a sample taken from its external cover was taken with an annealed platinum loop in order to be tested for sterility (for both aerobic and anaerobic bacteria). After this a longitudinal cut was made with fine scissors, the larva was opened with annealed needles along this cut, and the intestine drawn out in the Petri dish, care being taken not to damage it (larvae with a damaged intestine were excluded from the material). This done, separate segments of the anterior, middle and posterior intestine to be sown were cut out with a sterile scalpel and, with the aid of an annealed platinum

Bactericidal Properties of the Intestine of *L. sericata* Mg., *M. domestica* L. and *C. erythrocephala* Mg. at Various Periods of their Life

Species	Age of the larvae	Number of the individuals examined	Control				Anterior intestine				Middle intestine				Posterior intestine			
			aerobic		anaerobic		aerobic		anaerobic		aerobic		anaerobic		aerobic		anaerobic	
			+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−
L. sericata	II stage	10	1	9	1	9	10	0	10	0	10	0	8	2	2?	8	0	10
» »	III »	10	1	9	0	10	10	0	10	0	10	0	9	1?	8	2	5	5
» »	Diapause	8	0	8	1	7	8	0	8	0	8	0	8	0	8	0	4	4
M. domestica	II stage	10	2	8	1	9	10	0	90	0	9	1?	7	3	0	10	0	10
» »	III »	9	0	9	1	8	8	1	9	0	9	0	9	0	8	1	4	5
C. erythrocephala	I »	2	0	2	0	2	2	0	2	0	2	0	1	1	0	2	0	2
» »	II »	9	1	8	0	9	9	0	9	0	9	0	9	0	1	8	0	9
» »	III »	12	0	12	1	11	12	0	12	0	12	0	7	5	7	5	0	12
» »	Diapause	7	0	7	0	7	7	0	7	0	7	0	7	0	6	1	1	6

needle, transferred separately to sterile watch-glasses, containing several drops of saline, emulgated by means of a glass rod and resown into nutrient media. Sowing was practised in test-tubes: for aerobes, into meat-pepton broth and meet-pepton-agar; for anaerobes, into Kitt—Torozzi's liver-medium and Wilson—Blair's medium. Further observations were carried out in a thermostat, at a temperature of 37° C, during 48—72 hours.

The investigation embraced larvae of *L. sericata*, 10 individuals at the II stage, 10 at the III stage and 8 at the state of diapause; of *M. domestica*, 10 individuals at the II stage and 9 at the III stage; of *C. erythrocephala*, 2 individuals at the I stage, 9 at the II stage, 12 at the III stage and 7 at the state of diapause*. The results of examination are given in the table.

What should be noticed in the first place is the absence in the posterior intestine of the larvae of all the three varieties at earlier stages of their development of either aerobic or anaerobic bacteria. The growth of aerobic cultures sown from the anterior intestine, that was observed in one case for *C. erythrocephala* larvae of the II stage, and in two doubtful cases for *L. sericata* larvae of the same stage, cannot serve to refute this statement: first, the larvae could possibly belong to more advanced stages, and, secondly, in these cases, the possibility is not excluded of a casual infection with aerobic bacteria. Larvae of the III stage of all the three fly-species not unfrequently give bacterial growth from their anterior intestine. The highest percentage of growth was obtained from tests for aerobic bacteria; as to anaerobic microflora, it is absent in larvae of *C. erythrocephala*, and was observed occasionally in larvae of *M. domestica* and *L. sericata*. Larvae of *L. sericata* and *C. erythrocephala*, at the stage of diapause, like those of the III stage, contain a rather abundant microflora in their posterior intestine.

Several III stage larvae of the three species had been subjected prior to examination to cooling at 4° C during four 24-hour days. Sowing from their posterior intestine showed invariably a highest degree of infestation with microorganisms,

* The age of the larvae was determined by Prof. I. V. Kozhanchikov.

both aerobic and anaerobic in *L. sericata*, and only aerobic in *C. erythrocephala*.

From all the above data the following conclusions can be drawn:

1. The larvae of flies show the most intense secretion of active bactericidal principle at early stages of their development.

2. Treatment with low temperature during a long period of time, which undoubtedly results in a suppression of the general tonus, seems to call forth a decrease in the vitality and secretory activity of the larvae.

3. The bactericidal properties of *C. erythrocephala* larvae exceed those of the two other varieties as to stability against anaerobic microflora.

These conclusions are of unquestionable practical interest. They are also helpful in interpreting some data that have been known of late. Thus, W. Baer ([3]), the originator of larvae therapeutics, has pointed out that the larvae applied to a wound must be renewed every 5—6 days, since they cease to produce any effect after having reached a definite stage. Baer, who regarded the larvae from the standpoint of their «sanitary» work only, explained the necessity of their regular renewal by nutrition alone. But it is not excluded that the necessity of this condition is accounted for by the drop in the intensity of the secretory activity, which characterizes the larvae of more advanced stages. Recently a method has been suggested ([2]) which consists in the application to the wounds of sterilized eggs, instead of sterile larvae. The advantage of this method may possibly be due to the fact that, when freshly hatched in a wound, the larvae excrete into the latter greater quantities of the active principle. In the light of what has been reported above, the method of treating wounds with eggs deserves particular attention. The observations made by Prof. S. A. Novotelnov also go to confirm the fact that the secretory activity of larvae is suppressed by treatment with low temperatures. As has been reported by Novotelnov, some of the test-tubes were found to contain sterile larvae that gave a very weak effect, irrespective of the fly-species. And this were precisely those tubes which prior to the experiment had been kept during 7—9 days in a refrigerator. Therefore the method of keeping of the larvae for long periods in refrigerators, as suggested by some surgeons ([4]), should decidedly be rejected. The resistance of the *C. erythrocephala* larvae to anaerobic bacteriae, which has been observed by the author, deserves thorough attention and stands in need for further investigation.

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PHYSIOLOGY

EVOLUTION OF THE RESPECTIVE RÔLE OF AND CORRELATION BETWEEN HUMORAL AND REFLECTORY FACTORS IN THE REGULATION OF BREATHING

The part of the aortal reflexogenic zone in regulating respiration and supporting the functional activity of the central nervous system of the frog

By B. P. KRAVCHINSKY

(Communicated by L. A. Orbeli, Member of the Academy, 23. IV. 1943)

The question as to the nature of regulation of breathing in amphibians is a controversial one. Bethe, Baglioni (1907), Winterstein (1912), Wittich (1866) and many others arrived at a conclusion that the frog is endowed only with a reflectory and with no humoral regulation of breathing. Later investigators reported data in favour of the humoral nature of regulation (Babak, 1913; Karasik, 1928, 1934; Popov and Wagner, 1928, and oth.). They have shown the possibility of provoking dyspnoea in a frog when acted upon with chemical stimuli.

The presence of vascular reflexogenic zones involved in the regulation of breathing makes us assume a new attitude towards this problem, since dyspnoea may be due not only to a direct action of a chemical stimulus upon the respiratory centre, but upon the chemoreceptors of reflexogenic zones, as well.

For lack of morphological data as to the aortal nerve in the frog, I found myself obliged to trace the run of the aortal nerve by preparing and cutting the nerve under a binocular magnifying glass, and by analysing the nerve fibres and endings with the help of novocaine, nicotine and potassium cyanate. The aortal nerve in the frog branches off from the great aortal nerve, at a considerable distance from the place where the latter diverges from the main trunk of the vagus. Bilateral cutting of the vagi above the point of departure of the laryngeal nerves, as well as cutting of both laryngeal nerves above the point where they branch from the aortal ones, and cutting of the aortal nerves separately result, after a short-lived excitation, in a total stoppage of respiratory movements. Similar results are brought about by applying 1% novocaine solution to the laryngeal or aortal vagi, and by smearing with 1% novocaine solution the aortal reflexogenic zone in the region of the dorsal surface of the bulb and bifurcation of the aorta.

Characteristic dyspnoea is brought about in the frog by smearing the aortal reflexogenic zone with nicotine (1 : 10000) or potassium cyanate (1:1000).

After the laryngeal nerves have been cut above the point of origination of the aortal nerves, respiration stops altogether, and can be renewed neither by applying a chemical stimulus to the region of aortal bifurcation, nor by a general treatment with nicotine or potassium cyanate.

Smearing of the aorta bifurcation with nicotine (1 : 500) results at once in an irreversible stoppage of respiration. The cutting of these nerves or the application to the nerves or smearing of the aorta bifurcation with novocaine

calls forth, aside from an irreversible stoppage of respiration, a slowly developing inhibition of the entire nervous system, inclusive of the spinal cord. 10—15 minutes after the above-mentioned nerves are cut, the arising of Turk's reflex is considerably delayed; towards the 20th minute reflexes in response to acids disappear entirely, and the only left behind is the extensory reaction in response to strong mechanical stimuli. After 30—40 minutes irrevocably disappears the reaction both to mechanical and chemical stimuli. In most of the cases the contractions of the heart are sharply slowed down; occasionally the heart can even stop at the diastole, which leads to the death of the animal.

If the spine is cut within the region of the 3—4th segments, 15 minutes after a preliminary cutting of the vagi, there is no farther transmission of inhibition along the spine, and spinal reflexes from the hind legs may even reappear, while those from the fore legs vanish. After the spine is cut, the reflexes from the hind legs persist during many hours, inspite of the cutting of the vagi and an irreversible stoppage of respiration.

Full desympathization by means of the extirpation of both sympathetic chains does not eliminate the effect of inhibition of the central nervous system, following bilateral vagotomy. Unlike the classical Sechenov inhibition which, according to Tonkikh, is effected by way of the sympathetic nervous system, the phenomenon described above is a purely intracentral inhibition.

A preliminary extirpation of the frog's brain above the medulla oblongata does not prevent the effect of inhibition of the central nervous system, ensuing after bilateral vagotomy. The destruction of medulla oblongata eliminates the said inhibitory effect. The process of inhibition resulting from bilateral vagotomy arises in the region of medulla oblongata, wherefrom it slowly propagates along the spine. It is the slow propagation (in the course of some dozen minutes) of the process of inhibition of the central nervous system following bilateral vagotomy, which ultimately results in the death of the animal, that makes us assume a humoral nature of the process described.

Neither preliminary atropinization and chloralhydrate narcosis, nor curarezation of the frog are apt to eliminate the effect of irreversible stoppage of respiration and the inhibition of the functional activity of the central nervous system that follows a bilateral vagotomy. The investigation of this problem is in progress. From the above said it may be concluded:

1. The aortal reflexogenic zone of the frog, situated in the region of the bulb and bifurcation of the aorta, is endowed with highly sensitive chemoreceptors; the latter serve as a source of the afferent impulses that are responsible for the respiratory movements of the frog. The cutting of the afferent nerves proceeding from the reflexogenic zone referred to above, as well as the application of novocaine, result in an irreversible stoppage of breathing. The data obtained by the author make him believe that the frog is endowed only with a reflectory regulation of breathing.

2. The data reported above make one think of the absence of automatism in the respiratory centre of the frog, and of the «autochtonism» in the activity of its central nervous system, or else of an inhibition of these processes upon elimination of afferent impulses. In cases there are no afferent impulses from the vessels of the reflexogenic zone, the process of irreversible inhibition involves the whole central nervous system of the frog.

3. According to data by C. Schmidt, the vascular reflexogenic zones (the aortal and the sinocarotic zone), which are rudiments of the primitive gill vascular system of the embryo, play no essential part in the normal regulation of breathing in mammals, being an *ultimum moriens* in their respiratory regulatory system. In lower vertebrates, viz. amphibians, their rôle in the regulation of breathing and in the support of the functional activity of the whole central nervous system is of paramount importance.

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HELMINTHOLOGY

NUMEROSITY OF *MUSTELA ERMINEA* PALL. AS AFFECTED BY *SKRJABINGYLUS* INVASION

By V. A. POPOV

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To bring out the causes which underly the variation in the numerosity of valuable fur animals and to work out more accurate methods for the prognostication of their «yields» is one of the most important problems of to-day. As seen from recent investigations, the analysis of meteorological data and of variation in food conditions is not always sufficient to prognosticate correctly the yield of the ermine, one of the most valuable species of animals hunted for their fur in this country. It has been found that, along with the factors mentioned above, variation in the numerosity of the ermine is strongly affected by the degree of its invasion with parasitic worms.

Fig. 1

Examining a series of *Mustela erminea* skulls, we discovered a considerable number of skulls bearing traces of deformation in the region of the frontal sinuses. These alterations were sometimes in the form of swellings of the bone, usually asymmetrically situated. Occasionally there was perforation of frontal bones (Fig. 1). The frontal sinuses of such skulls were often found to contain parasites belonging to the genus *Skrjabingylus* Petrow, 1927.

Data obtained from external examination of the skulls enables us to diagnosticate, leaving the skull intact, infection with *Skrjabingylus* not only in the ermine, but in some other *Mustelinae*, as well. Materials collected by the Volga-Kama scientific station of one of the concerns have been accordingly treated by the author. The results are summarized in the table. The material refers to three hunting-seasons, viz. 1928—29, 1929—30, 1930—31.

The high percentage of damaged skulls and the considerable pathological alterations called forth by the parasite (atrophy and perforations of bones in the region of frontal sinuses) cannot possibly leave unaffected the vitality of the population. They must be taken into account when studying the numerical variation of such species as *Mustela erminea* and *M. nivalis*. It is illustrative that the body weight of an ermine male invaded with *Skrjabingulus* is 164.3 g, while that of a healthy animal amounts to 174.4 g.

The feeding condition of the animals, as appraised according to the four-point system, is 1.0 for healthy animals, and 0.6 for animals invaded with *Skrjabingylus*. The data on weight and feeding condition have been obtained from the treatment of 103 specimens of male *Mustela erminea* killed in the course of the 1938—39 hunting-season.

Species	Number of skulls examined	Out of them infested	
		Number	%
Martes m. ruthena Ognev	60	8	13.3
Putorius p. putorius Linn.	136	21	15.4
P. eversmanii e. Lesson	96	16	16.6
Kolonocus sibiricus sibiricus Pall.	34	4	11.8
Lutreola lutreola Linn.	53	11	20.8
*Lutreola vison** Briss.	59	9	15.3
Mustela erminea aestiva Kerr.	178	42	23.6
Mustela nivalis nivalis Linn	52	22	42.3
	608	133	29.9

* The skulls of American lutreolae were collected in 1938—39 from animals acclimatized in the Tatarian ASSR.

The pathology and the mode of spreading of parasites belonging to the genus *Skrjabingylus* have been but poorly investigated. Petrov (3) has found *Skrjabingylus nasicola* (Leuckart, 1842) in the frontal sinuses of *Mustela nivalis*. Morosov found the said parasite in 2 out of the 10 ermines dissected by him (4). Petrov (5) discovered this nematode in *Mustelinae* of the Moscow Zoological Gardens. Petrov and Gagarin (6) found in animals of the Pushkino Collective Farm a parasite closely approaching *Sk. nasicola*. This parasite was described in 1936 by Bageanow who gave it the name of *Skrjabingylus petrowi* Bageanow. As established by Petrov and Gagarin, the intermediate host of this parasite is the on-land mollusc *Suecienea putris* L. On the 2nd day upon infestation of the mollusc, one can see larvae of the parasite invaginate into the peduncle of the mollusc. Towards the 17th day, having passed through two moults, the larvae transform into invasional larvae of the third stage. When fed to a *Putorius*, the excrements of the animal have been found at the 18th day to contain larvae of the parasite, while in its frontal sinuses have been detected 5 sex-mature *Sk. petrowi*. Thus, the whole developmental cycle of the parasite is accomplished within 35 days.

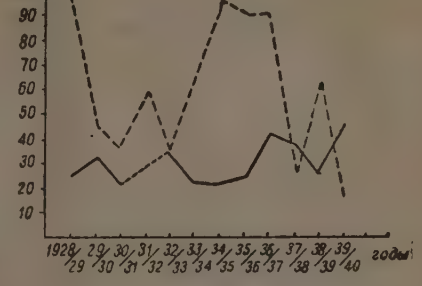

Fig. 2

In order to make clear the effect of the *Skrjabingylus* invasion upon the variation in the numerosity of *Mustela erminea*, the author examined 695 skulls of this species, collected in the course of eleven hunting-seasons, from 1928—29 to 1939—40. The degree of invasion with *Skrjabingylus* has been found to fluctuate between 20.9% (in 1930—31) to 45.2% (in 1939—40). The average figure thus amounts to 27.9%. In all cases we speak here of a relative infestation which is the only one we could establish from the external inspection of the skulls.

No clear-cut correlation between the degree of infestation and the sex of the animals could be observed. But it was found to vary considerably with age. The infestation of young (7—10 months old) makes up 14.8%; the highest figures coincide with the II (42.3%) and III (44.9%) age; the IV age yields 40.5% of infested skulls; the V one. 38.9%; and the VI. 14.3% only. This circumstance seems to us to be evidence of the mortality among animals infested with *Skrjabingylus*, since it is scarcely probable that deformed

frontal bones can be restituted so as to bear no traces of former destruction.

From a comparison of the data on infestation of the ermine, as obtained for separate hunting-seasons, with the variation in the numerosity of ermine populations, which may correctly enough be estimated from the fur-provisions, it can be seen that between the two factors there exists an inverse correlation (Fig. 2). During those years when the ratio of invaded skulls increases, the numerosity of the animals is seen to drop (storage of furs). The discrepancy observed for 1930—31 may largely be accounted for by the fact that a considerable number of hunters abandoned at this period their trade and went to work in some branch of industry.

The correlation established by the author between the ratio of *Mustela erminea* invaded with *Skrjabingylus* and the numerosity of the population is quite significant. This correlation enables us to promote the study of the oecology of *Mustela erminea*, to work out a more precise method for prognosticating its yield. At the same time it focuses the attention of both oecologists, engaged in the study of mammals, and helminthologists, upon the necessity of studying the pathogeny of the skrjabingylosis, and the bio-oecology of the latter.

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ENTOMOLOGY

A NEW SPECIES OF THE GENUS *CARCELLIA (DIPTERA, LARVIVORIDAE)* FROM THE USSURI LAND

By A. A. STACKELBERG

(Communicated by L. A. Orbeli, Member of the Academy, 16. XII. 1942)

Owing to the kindness of Prof. E. N. Pavlovsky, of the Academy of Sciences, I received for determination one specimen of *Carcellia*, which had developed from a larva of *Monema flavescens* Walk. (*Lepidoptera, Limacodidae*); the larvae of this species of *Lepidoptera* were collected by A. I. Kurentzov on different broad-leaved species of trees, along the upper course of the Suputinka river, in the Ussuri Land, at the end of July 1939.

The group *Carcellia* is represented in most parts of the Palaearctic region by a small number (10—12) of species. Within the limits of eastern, and especially of south-eastern Asia, the group of forms allied to the genus *Carcellia* is represented by numerous forms, distinctly differing from one another; this fact enabled Baranov (1934) to subdivide the mentioned group into a number of genera. This division may hardly be considered correct: all the species of the *Carcellia* complex (as termed by Baranov) are more or less monotonous as to their morphology; hence it seems to be more advisable to consider Baranov's genera as subgenera. The new subgenus with the one new species described in the present paper is most closely related to the subgenus *Zygocarcellia* Townsend (1927), the only species of which is known from Formosa and the Large Sunda Islands.

Megacarcellia, subgen. nov. On the whole the subgenus is closely related to *Zygocarcellia* Town. (Townsend, 1927; Baranov, 1934), except for its ocellar bristles which are well developed and strong, and for its inner vertical bristles which are parallel and not crossing.

Mesonotum with four postsutural dorsocentral bristles. Middle tibiae with a strong ventral bristle. Claws in male strongly elongated. Posterior coxae without bristles behind. Abdomen with short dense hairs, without distal bristles. Eyes with short dense hairs.

Typus subgeneris: *Carcellia* (*Megacarcellia*) *pavlovskyi*, sp. n. Large species (15 mm long); in habitus similar to *Sturmia* (*Ugimyia*) *sericariae* Corn.; abdomen short, oval.

Head semiglobular; front protruding about as far as half of the eye-diameter, in the upper part about half as broad as the eye. 14—16 frontal bristles, two of them strong, reclinate. Ocellar bristles long and strong, directed forwards. Frontal stripe a little broader than the orbite. Orbites greyish-white, silvery, with long and dense black hairs. Cheeks somewhat broad, narrowing downwards, silvery, bare. Jaws narrow, about one fifth of the height of the eye, greyish-white, with dense, black erect hairs. Occiput greyish-white, haired. Eyes with short dense whitish hairs. Palpi brown, blackish on basal half. Antennae in the type broken. Thorax black, with

dense brownish-grey tinge. Mesonotum with four black narrow stripes. Scutellum more or less reddish, slightly translucent. Abdomen black; 1+2 tergits black; the three last tergits with broad pale-greyish bands covering just the front half of the segments; the hind margins of the segments and a generally narrow middle line black. Abdomen short, haired, with marginal bristles only: a pair on the second (1+2) and third and a row on the fourth segment; distal bristles absent. Third tergit below without hairy side-spots. Hypopygium small; cerci viewed from behind on the basal half broad oval, on the apical half narrow and long, in profile slightly and uniformly bent; coxite rather broad; penis with a notch at the top. Wings almost hyaline, a little brownish at the base; r_{4+5} with 5 small bristles at the base. Squamae yellowish-white. Legs black. Middle tibiae with one strong ventral bristle. Hind tibiae with a characteristic anterodorsal fringe of long dense bristles.

Geographical distribution: Ussuri Land, upper course of the Suputinka river, VII. 1939. 1 ♂ was bred from a larva of *Monema flavescens* Walk. (*Lepidoptera, Limacodidae*) collected by Dr. A. I. Kurentzov. Type in the collection of the Zoological Museum, Academy of Sciences, Leningrad.

Zoological Institute.
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